N. K. MATHUR
Librarian

T. C. JAIN
Asstt. Librarian

G. C. BHARDWAJ
Asstt. Librarian

G. L. SAINI
Asstt. Librarian

S. M. S. MEDICAL COL
J A I P U R--302004

CONTENTS



SURGICAL HANDICRAFT

CHAPTER I

THE ARREST OF HÆMORRHAGE

By Hamilton Bailey

"Bis dat qui cito dat"—"He gives twice who gives it quickly."

I. BY DIGITAL COMPRESSION

The immediate treatment of a wound of any large artery is to apply pressure to the bleeding point with the left thumb, while the right hand seeks the point of vantage to compress the artery above the wound.

Because of the fatigue it produces, digital compression to the point of vantage cannot be continued for more than ten minutes or a quarter of an hour. Long before that time, however, help may have arrived, or an improvised tourniquet may have been applied.

The position of the hand and finger to be employed will vary, but as a rule it is better to employ the thumb for making the pressure, reinforcing it,



Fig. 1.—The control of hæmorrhage from the lip by compressing the labial arteries.

when necessary, by the thumb of the other hand. The limb must always be raised. Attention is now directed to pressure points of vantage.

Arteries of the Head and Neck.—*In cases of injury to the scalp, the underlying skull affords an admirable resisting surface for compression.*

Bleeding from the lip forms an exception to the rule of making digital compression against bone, for the labial arteries are best compressed between the index fingers and thumbs (*Fig.* 1).

Bleeding from the Tongue.—When hæmorrhage occurs from the posterior part of the tongue, Heath's *method should be employed.* A finger is passed as far back as possible and the tongue is hooked forward on to the mandible.

Common Carotid Artery.—The thumb should be placed over the artery at the level of the transverse process of the sixth cervical vertebra, which is about 1½ in. (3 75 cm.) above the sternoclavicular articulation; pressure should then be made *inwards* and backwards. In this way the artery is forced away from the jugular vein and vagus nerve, and is compressed against the sixth transverse process (Chassaignac's tubercle) (*Fig.* 2).



Fig. 2 —Compression of the common carotid artery over Chassaignac's tubercle. A, *Pomum Adami*; B, *Cricoid*, C, Sternal notch

Subclavian Artery.—Only the third part of the subclavian artery can be compressed; this is sometimes difficult and sometimes easy to perform.

The bone against which it is to be compressed is the upper surface of the first rib, immediately lateral to the scalene tubercle. [illegible] downwards, backwards, and *inwards* (*Fig.* 3). In even moderately fat people it is necessary for an assistant to exert downward traction on the arm in order to bring the artery near enough to the surface.

Various devices, such as the handle of a door key, properly padded, have been adopted to effect the necessary compression in obese and muscular individuals

Axillary Artery.—The lower half of the second part, and the third part, are tolerably superficial, and can be compressed in the axilla if the arm is raised. The pressure is made against the humerus in the same manner as for the brachial artery (*see below*), and the vessel can be localized quite easily as it crosses to the outer side of the axillary space



Fig 3 – Compression of the third part of the subclavian artery downwards and backwards onto the first rib

Brachial Artery.—By reason of the number of accidents to which the upper limb is liable, this artery requires compression more frequently than all the others put together.

As the brachial artery is practically subcutaneous in its whole length, it can be compressed readily against the humerus The inner edge of the biceps, which overlaps it in the middle third, is the guiding line for the vessel (*Fig.* 4).

Femoral Artery.—Owing to the frequency of compound fractures of the lower limb, compression of this artery as it lies over the pelvic brim is required fairly often In this situation the circulation may be completely controlled by making pressure directly backwards, i.e., at right angles to the surface, midway between the symphysis pubis and anterior superior iliac spine (*Fig* 5)

The line of the *superficial femoral artery* is one taken from the point above mentioned, between the symphysis pubis and anterior superior iliac spine, and the adductor tubercle of the femur. When the knee is slightly flexed, and the thigh rotated outwards, firm pressure all along this line will generally succeed in stopping



Fig 4.—Compression of the brachial artery It is correct to employ the fingers for this purpose



Fig 5.—Compression of the common femoral artery

the current of blood; but as the artery gets deeper in its course, more and more force is required. The artery cannot be pressed directly against the bone.

Abdominal Aorta.—In some cases the digital compression of this artery is not so extremely difficult as is often supposed. It can generally be effected in children, and in adults if they are thin, with lax abdominal walls and a bold anterior vertebral curve, and especially in women who are sparely nourished and have borne children.

The spot where this compression should be made is a point ¾ in (1·8 cm.) above a line drawn across the abdomen from one iliac spine to the other (the level of the aortic division into the two common iliacs), and a little to the left of the middle line.

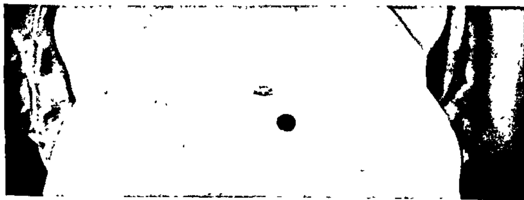


Fig 6.—The spot at which to compress the abdominal aorta

(*Fig*. 6.) The exact position of the artery should be ascertained before pressure is made, for frequently it is in the middle, or may even deviate somewhat to the right.

The digital compression is best and most readily made by the middle finger and forefinger of one hand, beneath which a small pad of lint should be placed, reinforced by the pressure of the fingers of the other hand.

II. BY TOURNIQUETS

TOURNIQUETS—IMPORTANT RULES

1. Whoever puts on a tourniquet must make himself responsible for taking it off
2. In an operating theatre the time of putting on a tourniquet should be chalked on the blackboard or slate.
3. Whoever writes the time on the slate must be responsible for calling: "Has the tourniquet been removed completely?" before the patient leaves the operating theatre.

Tourniquets are employed: (1) to arrest hæmorrhage; or (2) to ensure a bloodless field during certain operative procedures on limbs. There is not a better demonstration of the old adage "it does more harm than good" than a badly applied tourniquet. A tourniquet applied unnecessarily tightly can do great harm; one which is not tight enough fails to arrest arterial blood-loss, and increases venous hæmorrhage. For instance, do not rush to apply a tourniquet in every case of bleeding from a limb; unless the hæmorrhage is catastrophic it can be controlled by a pad and bandage.

I was called to see a man who had sustained a wound in the thigh and was in the last stage of exsanguination therefrom. There was a tourniquet in place above the wound, but it was so loose that my fingers could be insinuated beneath it. The femoral artery was intact, but there was a large opening in the femoral vein.

A tourniquet must never be left unreleased for more than thirty minutes. If by the end of this time compression is still necessary, the tourniquet should be loosened sufficiently to allow some blood to escape, when it is tightened once again. In this way gangrene may be averted.

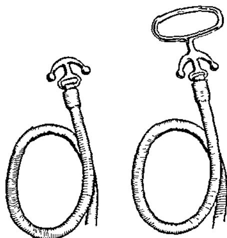


Fig 7.—Samway's tourniquet.

Fig. 8.—Callander's modification of Samway's tourniquet.

The application of a tourniquet consists of two manœuvres:—

1. Elevation of the limb. This allows the venous blood to drain away by gravity, and at the same time produces a reflex constriction of the arterioles. This latter effect occurs after a period of elevation of about two minutes. Lord Lister demonstrated this by the sudden blanching of a limb which occurs when it has been held up for that length of time.

2. The application of the constricting agent. Of the many patterns of tourniquet available only a few can be described.

Samway's Tourniquet. — This consists of a length of stout rubber tubing with an anchor-shaped metal clip attached to one end (*Fig.* 7). Callander's modification (*Fig.* 8) enhances the ease of application. The rubber tubing should be soft and pliable, and of wide bore—almost 1 in. (2·5 cm)

A tourniquet of the Samway type should always be tested before it is applied. This is done by holding the anchor in one hand, the free end in the other, passing the tube round the shoulders and pulling down hard with both hands for a few moments. It is too often assumed that tourniquets are everlasting, and forgotten that many lie unused and uncared for for months at a time. To have at the bedside of a patient who has had a leg amputated, and who may be expected to have a secondary hæmorrhage, a Samway's tourniquet which has not been tested is an act of negligence that may readily cost the patient his life.

The limb is elevated by an assistant, and at the end of two minutes the tourniquet is applied. The scrotum is held well out of the way. The skin is



Fig. 9.—The application of Samway's tourniquet. The first turn.



Fig. 10.—The application of Samway's tourniquet. Locking the tubing in the anchor.

protected by several layers of towelling or lint. The most important turn is the first; every endeavour should be made to make it as tight as possible. The anchor is held against the limb with one hand, while the rubber tubing is passed behind the limb and then stretched to its utmost by the other hand (*Fig.* 9). In order to get a good purchase, a fairly short length of the tubing is stretched in this way.

Keeping the tube stretched, it is applied to the limb, and when the turn is completed it is gripped by the thumb and index finger of the hand holding the anchor. Another two or three turns are similarly obtained, and the free end held by passing it, still stretched, behind the flukes and over the shaft of the anchor (*Fig.* 10). Care should be taken to see that the skin is not pinched between the loops. This is a useful tourniquet for the thigh, but it should not be employed for the upper limb—the integrity of nerves, especially the radial

(musculospiral), is endangered. When it is desired to maintain the tourniquet at the highest possible level on the limb, transfixion pins or a loop of bandage passed over the contralateral shoulder may be used to maintain it there.

The Pneumatic Tourniquet.—Several patterns are available. The cuff of a sphygmomanometer is a pneumatic tourniquet. A pressure of 200 mm. Hg will usually ensure avascularity of the arm without damaging nerves or muscles. (*See Fig.* 584, p. 483.)

Esmarch's Bandage is made of strong flat rubber, 3 in. (7·5 cm.) wide by 6 yd. (5 5 m.) long, with two tapes at one end.

The limb is elevated, and after an interval the rubber bandage is wound around the limb from below upwards. Each turn of the bandage is fully stretched

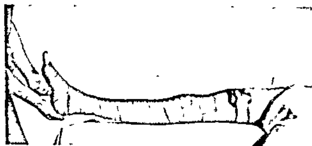


Fig 11.—Esmarch's bandage applied.

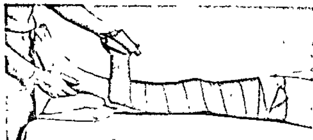


Fig. 12 —Beginning below, the bandage is removed The major portion of the bandage is unwound

before being applied to the limb, and each turn should just meet edge to edge, or barely overlap, the preceding one. When the middle of the thigh or arm is reached, several turns are made directly over each other, and the tapes tied. If there is still a considerable quantity of the roll left, it is tucked under the last two or three turns (*Fig* 11), instead of unrolling it, so as to act as a pad and apply direct pressure on the femoral or brachial artery. Beginning below, the bandage is now unwound (*Fig.* 12) as far as is necessary to expose the field of operation. There is no danger of the upper part becoming loose if the Esmarch's bandage has been applied correctly If the turns are made to overlap too much, difficulty will be encountered in unwinding the bandage

Esmarch's bandage is unsuitable for use in cases of trauma unless applied to the proximal part of a limb only, where other patterns serve better. Its use is unsafe in cases of severe sepsis.

III. OTHER METHODS

Where facilities are available bleeding is controlled :—

1. By Direct Ligature.—This is the method of choice, and the end to which temporary expedients are usually directed. If necessary the wound is enlarged, and the bleeding vessel secured. Both ends of a large vessel must be tied

2. By Suture.—Suture of a tear in the wall of a large artery, or end-to-end anastomosis of severed blood-vessels should the adequacy of the collateral circulation be doubtful, are beyond the scope of this work

3. By Packing.—If the bleeding point cannot be identified, external hæmorrhage can be controlled by firm packing of the wound with dry gauze, preferably moistened with flavine, and held in place by a pad of wool and firm bandages. This method may be used temporarily in anticipation of an operation for ligature. It will follow the application of a tourniquet in circumstances of emergency, particularly if the patient must make a journey, the tourniquet then being slackened, when its continued use is often found unnecessary. The pack, if inserted in an operating theatre, is allowed to remain in situ for two to seven days, depending upon the size of the vessel which is supposed to be the source of the bleeding.

Packing and firm bandaging will always control venous hæmorrhage, not only as a temporary measure, but as a final method, the wound being repacked at weekly intervals with petroleum-jelly gauze.

In all cases where packing is employed, it is advantageous to moisten the first portion of the gauze with Russell's viper venom.

The venom is kept in a dry state, to prevent decomposition, and is applied in 1–10,000 dilution. Of several preparations, the best known is Stypven (Burroughs Wellcome & Co.).

Gelatin foam (Gelfoam* ; Sterispon†), oxidized cellulose (notably Oxycel)‡, and fibrin foam, all of which are absorbable, can be used with advantage in the deep part of the wound.

THE CONTROL OF HÆMORRHAGE IN HÆMOPHILIA

By F. H. Robarts

In hæmophilia it is the coagulation time of the blood that is prolonged unduly. The control of the bleeding tendency becomes a matter of very great importance when a hæmophilic patient has to undergo any surgical operation, especially if the patient is in a bleeding phase.

Local treatment (where applicable) : A pressure dressing, combined with the application of a thromboplastic substance—Russell's viper venom, fibrin foam—is of value.

Systemic treatment Transfusion of *fresh* whole blood of up to 100 ml. will suffice to bring about cessation of bleeding Larger amounts, of course, will be required to replace lost blood. Should the patient remain in a bleeding phase after the effect of this transfusion has worn off (two or three days) further transfusion will be required. For use by an intramuscular injection, an antihæmophilic

* The Upjohn Company.
† Allen and Hanburys Ltd.
‡ Parke Davis and Co. Ltd

factor derived from the α globulin fraction of the plasma of normal blood is becoming available from Regional Blood Transfusion Centres.

Threatened Asphyxia.—Tracheal intubation* may be demanded urgently for [illegible]

(accomplished most easily in children by the administration of brandy) or, as a last resort, by evacuation of the hæmatoma by aspiration or incision.

Hæmarthrosis usually affects a knee-joint. The application of a pressure bandage causes an exacerbation of acute pain. Immobilization of the limb in extension provides [illegible]

THE CONTROL OF HÆMORRHAGE IN THE NEWBORN

During the first week of life, usually between the third and fourth days, spontaneous hæmorrhage sometimes occurs into the alimentary canal, when it is evidenced by melæna or the passage of fresh blood per rectum, or by hæmatemesis; from the umbilicus (when it is likely to be due to insecure ligation of the cord); from the nose and mouth; or into the skin and subcutaneous tissues at points of pressure. Bearing in mind the small blood-volume of the infant, [illegible]

prematurity it is sometimes even lower.

Treatment.—Hypoprothrombinæmia can be countered rapidly by the administration of a water-soluble analogue of vitamin K† in an intramuscular dose of 5 mg. If necessary, this dose may be repeated in 12 hours. In addition, blood transfusion should be carried out as soon as possible in necessary cases. In bleeding from the umbilicus local treatment, apart from the placebo use of styptic, is seldom necessary.

---

* Alternatively tracheotomy must be performed

† Synkavit (Roche), Kapilon (Glaxo).

CHAPTER II

THE TREATMENT OF SHOCK

By HAMILTON BAILEY

"*Restoration of blood volume is the most effective single therapeutic measure in combating shock.*"—C. K. Anderson, 1954.

SHOCK, more descriptively called peripheral circulatory failure, ensues when the volume of circulating blood is insufficient to fill the blood-vessels completely; consequently the physical signs—pallor, increased pulse-rate, decreased systolic blood-pressure, a cold clammy skin, and subnormal temperature, are identical with those of severe hæmorrhage.

Seldom is there difficulty in recognizing immediate primary shock following a major accident or operation.

The chief perplexity is to distinguish delayed shock*—delayed for as much as three to six hours—from myocardial failure, including coronary infarction, especially in the elderly; to supplement the circulating fluid rapidly in such catastrophes is often to determine a fatal issue.

The longer shock is allowed to persist, the more difficult is it to remedy. A time is reached when all efforts to revive the patient prove transitory or unavailing, for, owing to anoxæmia, the vital centres have sustained irreparable damage; the terminal stage, known as irreversible shock, has been reached.

In peripheral circulatory failure one should visualize as much as one-quarter or one-third of the total 10½ pints (6 l.) of blood of an average adult pooled in the dilated peripheral arterioles and flaccid capillaries, and fluid components of the blood transuding through the capillary walls into the extracellular tissue spaces, and direct treatment accordingly.

First Aid.—Elevation of the limbs is a method of postural treatment eminently suited to first aid. Standing astride the head of the supine patient, the legs are raised vertically. Further [illegible]



Fig 13.—Invoking the aid of gravity in the first-aid treatment of shock.

Morphine.—For a patient who is in great pain, and who was in perfect health at the time of the accident or wounding, the administration of morphine, which brings 'psychic immobilization', has received unquestioned world-wide approbation over many decades. *In this instance the drug must be given intravenously.* One-sixth or ¼ gr. (10–16 mg.), never more (in civil practice the smaller dose is advised), is diluted to at least 1 ml. with sterile water, and is injected over a period of not less than

* Also called 'oligæmic shock' because the reduced volume of circulating blood produces signs identical with those of severe hæmorrhage. Greek, ὀλίγος = *little* + αἷμα = *blood.*

one minute. In patients suffering from shock subcutaneous or intramuscular injection of morphine is avoided rigorously, because the drug is often not absorbed when it is needed. Repeated doses may accumulate, and, during the stage of recovery, have been known to cause death from delayed absorption.

IN-PATIENT TREATMENT (INCLUDING POST-OPERATIVE SHOCK)

Posture.—The foot of the bed must be raised at least 18 in. (46 cm.) (*Fig.*14). One flat pillow alone is permitted. Of all the methods of blocking beds, none has ever improved upon the late Willy Meyer's 'steps' (*Fig.* 15) which are used at the Lennox Hill Hospital, New York, for blocking, very effectively, either the foot or the head of the bed at a desired height. They can be made by a jobbing carpenter.

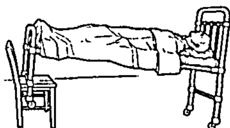


Fig 14—An effective method of blocking a bed.

In the operating theatre the patient is placed in full Trendelenburg's position.

Charts.—During the crisis, there is no better method than an improvised half-hourly record.* Across the page are written the half hours, viz., 2.30, 3.0, 3.30 p.m. Spaces are provided for temperature, pulse, and blood-pressure readings in that order.

Firm Bandaging of the Extremities is strongly recommended The limb to be used for the reception of fluid therapy (if that has been decided upon) and the arm that is employed for recording the blood-pressure (*Fig* 16) are left unbandaged. The house surgeon, mindful of delayed shock, will do well to request, and if possible help in, the application of the bandages as a routine after severe operations. Such was my training. Bandages are only removed when the pulse is of satisfactory volume.

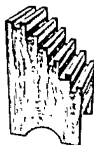


Fig 15—Willy Meyer's 'steps'

Application of Warmth is to be avoided The patient should be put to bed with the usual number of blankets, and the house surgeon should be vigilant to frustrate the well-meant efforts of the nursing staff to 'warm the patient up' (John Bruce) There is considerable experimental evidence to show that cooling (hypothermia) increases the resistance of the tissues to trauma and reduces their oxygen requirement by maintaining the vasoconstriction of the skin arterioles set up as a reflex in all forms of shock Heat cages, hot bottles, and electric blankets produce peripheral vascular dilatation—the very thing to be avoided.

Pressor Drugs.—

Methedrine (Burroughs Wellcome) 15–30 mg. intramuscularly, or 10–20 mg. intravenously, has earned a deservedly great reputation. If given when the blood-pressure commences to fall during an operation, in a large percentage of cases an improvement is registered. When necessary, a maintenance dose of 10–20 mg. intramuscularly is given four-hourly

* In desperate cases the pulse-rate should be taken every 15 min. during the critical period.

✓*Cortisone*, 100 mg. 6-hourly intramuscularly, is the best remedy for collapse due to adrenal failure—a condition difficult to recognize. Such a condition should be considered when a state of profound shock arises after operation without other obvious cause. Cortisone is also of value in the shock of burns.

✓**Cross-matching.**—A specimen of the patient's blood must be taken for cross-matching *before* either dextran or plasma is given. The introduction of dextran, in particular, into the blood-stream often vitiates the accuracy of compatibility tests by causing pseudo-agglutination of erythrocytes.

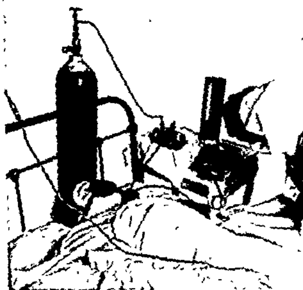


Fig 16.—Treatment of severe shock (due to a fractured pelvis) in progress. The sister is recording the blood-pressure

Dextran* is a complex polysaccharide produced by the action of non-pathological bacteria, particularly the *Leuconostoc mesenterioides*, on a substrate of sucrose and phosphate.

The organisms break sucrose into fructose and dextrose and synthesize dextran, which is composed entirely of dextrose containing molecules of various sizes. When introduced intravenously, if the molecules are too large they produce untoward reactions; if they are too small they are excreted by the kidneys rapidly. The undesirable molecules are eliminated by various processes in the manufacture of dextran.

Dextran shows little tendency to diffuse through the capillary walls, and at least 50 *per cent* of the solution should be retained in the body at the end of twenty-four hours. After that time some of it is excreted, and the remainder is catabolized slowly over about a week. These desiderata are reached by the commercial products listed in the footnote.

Infusion of 6 per cent Dextran in Normal Saline.—For technique of cannulization of a suitable vein, *see* pp. 70–72; for sternal puncture, *see* p. 93. Dextran is administered in exactly the same way as plasma. It can be stated that if

* *Plasma Substitutes*. Dextraven (Benger Laboratories, Holmes Chapel, Cheshire); Intradex (Glaxo Laboratories Ltd., Greenford, Middlesex).

dextran is used as directed here, it is very safe—safer than plasma and safer than Group O blood when the time factor prevents cross-matching.

Between 1 and 2 per cent of patients have untoward reactions during or following the infusion of dextran. This takes the form of pyrexia, with or without generalized urticaria.

proceeding

According to the response of the blood-pressure, the contents of one or two bottles of dextran are gravitated into a vein *comparatively quickly*. Infrequently a third bottle may be required, but *on no account must this amount be exceeded*,



Fig 17.—Dried plasma is reconstituted by filling up to the mark with pyrogen-free distilled water

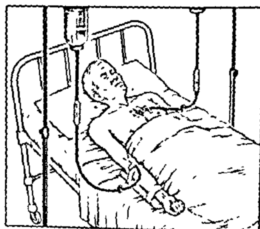


Fig 18.—Massive plasma infusion in progress. Dual intravenous and intramedullary infusions are being employed

or the patient's blood will become so diluted that its oxygen-carrying properties will become seriously impaired. As a rule, if more fluid therapy than the contents of two bottles of dextran is required, only correctly matched whole blood should be given.

Plasma Infusion.—One of the boons of plasma is that it can be ready for an emergency. Another is that cross-matching is unnecessary, but it carries a 1.3 per cent* risk of causing virus hepatitis. Plasma is usually supplied in a dried state (*Fig* 17) and can be kept almost indefinitely at room temperature. It is reconstituted by adding 400 ml. of sterile pyrogen-free distilled water, and shaking. This makes a normal strength solution.

Excellent results have been obtained in patients apparently moribund from

* If the plasma is derived from a pool of more than ten donors, the risk rises proportionately.

Two veins can be utilized simultaneously, or the bone-marrow of the sternum (*Fig.* 18) offers a valuable alternative route. In cases of profound shock, although a comparatively large vein has been entered, the plasma drips into it very slowly (owing to venospasm), whereas it runs into the bone-marrow without hindrance. As the condition of the patient improves, so the flow into the vein accelerates.

✓ In order to overcome venospasm 2–4 ml. of 1 per cent procaine can be injected into the tubing without danger, and is often effective.

Retrograde Intra-arterial Transfusion (*see* p. 105) with correctly matched whole blood is a method second to none for the treatment of established shock. It cannot be emphasized too often that only matched blood (or in cases of desperate urgency Group O blood) must be employed for this purpose.

Oxygen Therapy.—

Normally 100 ml. of arterial blood contains 19 ml. of oxygen combined with hæmoglobin and 0·3 ml. in solution—19·3 ml. in all. The administration of oxygen to a healthy person will not increase significantly the amounts of oxygen in his blood.

It has long been known that morphine lowers the blood-pressure and that oxygen restores it. Many shocked patients arrive (rightly) morphinized, and in theory and practice these subjects are ideal ones for the immediate administration of oxygen.

✓When efficient oxygen therapy (6 to 8 l. a minute) is given to a shocked patient, there is a rise in systolic blood-pressure of 20 mm. or more; if the oxygen is prematurely discontinued the blood-pressure falls, often rapidly (Melton). The total amount of oxygen that will be required for a single patient is considerable. Patients requiring oxygen frequently need it for 48–72 hours. One patient, therefore, may require 16–20 cylinders of oxygen. It will be realized that continuous oxygen therapy is expensive, but it is harmful to economize.

Morphinized shocked patients often tolerate the oxygen mask well, but there is no denying the fact that a number of patients needing oxygen will not endure the mask. In the absence of a special mask, or when the patient complains that the mask produces a sensation of impending suffocation, nasal catheters are quite efficient. Tudor Edwards's spectacle frame (*see Fig.* 303, p. 256) is an excellent addition for keeping the catheters in place.

The management of oxygen masks is dealt with on p. 255.

BLOOD-LOSS DURING OPERATION

In a given case of post-operative shock, it is difficult to be sure as to how much of the condition is due to loss of blood during the operation. To tabulate the average loss of blood at certain set operations will prove helpful.

Block dissection of the neck ..	899 ml. (1½ pt.)
Subtotal thyroidectomy	222 ml. (7½ oz.)
Radical mastectomy	1151 ml. (1 pt. 18½ oz.)
Subtotal gastrectomy for ulcer ..	855 ml. (1 pt. 8½ oz.)
Subtotal gastrectomy for carcinoma ..	1005 ml. (1 pt. 13½ oz.)
[illegible]	1289 ml. (2 pt. 3 oz.)
[illegible]	219 ml. (7½ oz.)
[illegible]	732 ml. (1 pt. 4½ oz.)
[illegible]	656 ml. (1 pt. 2 oz.)
[illegible]	613 ml. (1 pt. ½ oz.)
[illegible]	2037 ml. (3 pt. 8 oz.)
[illegible]	51 ml. (2 oz.)
[illegible]	541 ml. (18 oz.)

Herniorrhaphy : Inguinal	.. ..	73 ml. (2½ oz.)
Femoral	.. ..	40 ml. (1½ oz.)
Umbilical	.. ..	116 ml. (4 oz.)
Ventral	.. ..	347 ml. (11½ oz.)
Excision of varicose veins	.. ..	1121 ml. (1 pt. 17½ oz.)

(Saltzstein and Linkner's statistics from the Harper Hospital, Detroit)

THE TREATMENT OF SHOCK IN INFANTS AND CHILDREN

By F. H. Robarts

In the young, the effects of shock are liable to be more rapid and more profound than those produced by similar noxious stimuli in an adult. The reasons for this are physiological. The chief of these is the greatly increased metabolic demand for fluid in the infant and young child in whom the total blood-volume is much less in quantity but is greater in proportion to weight than it is in the adult. The following tables of *basic metabolic fluid requirements* for each 24 hours will be of service :—

Birth to 2nd birthday	160 ml per kg.
2 years to 4 years	100 ml. per kg.
5 years to 7 years	80 ml. per kg.
8 years to adult years	60 ml. per kg.

Having appreciated how relatively great is the daily requirement of fluid in the very young, it will be understood that loss of body fluid from open or occult hæmorrhage, on to the surface of burns and scalds and into the tissues adjacent to such injuries, from vomiting, and the reactionary effusion of generalized peritonitis can produce a state of profound shock with great rapidity.

As in the adult, treatment of shock is directed towards the maintenance of an adequate circulation and delivery of oxygen to the vital centres of the brain and medulla, the cardiac muscle, and to the kidneys.

Posture.—The elevation of the limbs and trunk and the 'head-low' position are generally applicable, and when there is any possibility of vomiting this position gives an additional safeguard against the aspiration of vomitus which is such a very real danger in infancy.

Sedation.—The avoidance of overdosage or of inadequate dosage through ignorance or enthusiasm is important Suitable doses of morphine are as follows :—

Morphine

$\frac{1}{32}$ gr. up to 6 months of age	$\frac{1}{12}$ gr. up to 8 years of age
$\frac{1}{24}$ gr up to 2 years of age	$\frac{1}{8}$ gr. up to 10 years of age
$\frac{1}{16}$ gr up to 5 years of age	$\frac{1}{6}$ gr. up to 12 years of age

The avoidance of the application of heat in any form. As in the adult, warming of the body surface only embarrasses the body's natural reactions to shock.

Pressor drugs are seldom if ever indicated in the young child.

Oxygen therapy can be of considerable value, and is administered most suitably through a nasal catheter with a flow of 3 litres per minute.

Fluid Therapy.—Provided there is no contra-indication to its use, the oral route is the safest for the administration of saline and dextrose. In babies

subcutaneous infusion of normal saline or half-strength normal saline, combined with 5 per cent dextrose, can be given and absorption aided by the addition of hyaluronidase. The intravenous route may, however, be necessary for speed of effect or from the nature of the substance required. At an approximate estimate, 15 ml. of crystalloid solution per pound of body-weight, and 10 ml. per pound of plasma or blood, may be safely given and the effect then carefully assessed before any more fluid is added to the circulation.

Charts.—For drip infusions careful recording of the rate of flow and the amount given is of vital importance. Recording of the passage of urine and if possible of the amount passed (obtained by indwelling catheter, if necessary) is the best method of assessing the adequacy of the circulation

Clinical Assessment of Progress.—The efficiency of the capillary circulation, the respiratory rate and rhythm, the mental state and behaviour, and the urinary flow (*see Table III*, p. 37) are the best criteria upon which to judge clinical improvement. The features of the pulse and the blood-pressure are useful but less indicative of the actual clinical state of the child.

Herniorrhaphy:	Inguinal ..	..	73 ml. (2½ oz.)
	Femoral ..	..	40 ml. (1¼ oz.)
	Umbilical ..	..	116 ml. (4 oz.)
	Ventral ..	..	347 ml. (11½ oz.)
Excision of varicose veins ..		..	1121 ml. (1 pt. 17½ oz.)

(Saltzstein and Linkner's statistics from the Harper Hospital, Detroit)

THE TREATMENT OF SHOCK IN INFANTS AND CHILDREN

By F. H. Robarts

In the young, the effects of shock are liable to be more rapid and more profound than those produced by similar noxious stimuli in an adult. The reasons for this are physiological. The chief of these is the greatly increased metabolic demand for fluid in the infant and young child in whom the total blood-volume is much less in quantity but is greater in proportion to weight than it is in the adult. The following tables of *basic metabolic fluid requirements* for each 24 hours will be of service :—

Birth to 2nd birthday	160 ml. per kg
2 years to 4 years	100 ml. per kg.
5 years to 7 years	80 ml. per kg.
8 years to adult years	60 ml. per kg.

Having appreciated how relatively great is the daily requirement of fluid in the very young, it will be understood that loss of body fluid from open or occult hæmorrhage, on to the surface of burns and scalds and into the tissues adjacent to such injuries, from vomiting, and the reactionary effusion of generalized peritonitis can produce a state of profound shock with great rapidity.

As in the adult, treatment of shock is directed towards the maintenance of an adequate circulation and delivery of oxygen to the vital centres of the brain and medulla, the cardiac muscle, and to the kidneys.

Posture.—The elevation of the limbs and trunk and the ' head-low ' position are generally applicable, and when there is any possibility of vomiting this position gives an additional safeguard against the aspiration of vomitus which is such a very real danger in infancy.

Sedation.—The avoidance of overdosage or of inadequate dosage through ignorance or enthusiasm is important. Suitable doses of morphine are as follows :—

Morphine

$\frac{1}{32}$ gr up to 6 months of age	$\frac{1}{12}$ gr up to 8 years of age
$\frac{1}{24}$ gr up to 2 years of age	$\frac{1}{8}$ gr up to 10 years of age
$\frac{1}{16}$ gr. up to 5 years of age	$\frac{1}{6}$ gr. up to 12 years of age

The avoidance of the application of heat in any form. As in the adult, warming of the body surface only embarrasses the body's natural reactions to shock.

Pressor drugs are seldom if ever indicated in the young child.

Oxygen therapy can be of considerable value, and is administered most suitably through a nasal catheter with a flow of 3 litres per minute.

Fluid Therapy.—Provided there is no contra-indication to its use, the oral route is the safest for the administration of saline and dextrose. In babies

1. (One second). The bases of the operator's palms are placed on the upper edges of the scapulæ with the fingers spread obliquely outwards and downwards.

2. (Two seconds). The operator rocks forwards slowly with straight elbows, until his arms are nearly vertical (*Fig.* 19 A), exerting steady pressure on the thorax.

3. (One second). He then rocks slowly backwards, sliding his hands to the victim's arms above the elbows, which are grasped as he continues to rock backwards.

4. (Two seconds). Raising the victim's arms (*Fig.* 19 B) until tension is felt, the arms are drawn *slightly towards himself*. Finally he lowers the arms, which completes the cycle.

Performed in this way, about ten respirations are carried out each minute.

The Direct Method was employed by **Elisha.**—" And he put his mouth upon his mouth." It is still valuable, especially in infants and children and in cases of fractured ribs where pressure on the thorax is contra-indicated. A handkerchief is placed over the mouth or nose and the operator blows through it gently. In children, it is better to blow through the mouth, so as to avoid possible obstruction by adenoid tissue. When inflating the lungs through the mouth the nose should be pinched and the chin held forwards. When inflating through the nose, the mouth must be kept closed. The breath easily enters and inflates the lungs, and it is expelled preferably with the help of gentle pressure on the chest or abdomen. The process is repeated every five seconds. (*Fig.* 20.)

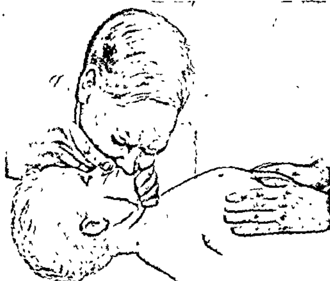


Fig. 20.—The direct method of performing artificial respiration

Silvester's Method (*Fig.* 21).—Provided there is no contra-indication (e.g., drowning; air embolism) to keeping the patient on his back, Silvester's is a well-tried method that has stood the test of



A



B

Fig 21 —Silvester's method of artificial respiration A, Inspiration , B, Expiration.

a contra-indication, but it adds a decided risk to operation. Those forms which are readily diagnosed and which can be compensated by appropriate management cause less anxiety than coronary disease, where there is so often degenerative change in the heart muscle. Even in the latter condition really necessary operations may be undertaken, especially since the relief afforded often benefits the cardiac mischief. Conditions which threaten life, such as strangulated hernia, perforation of a viscus, or acute appendicitis, must be dealt with by the simplest possible measures. Local anæsthesia, combined if necessary with a minimum of gas and oxygen, will suffice for most such operations. It is best if the appropriate method can be discussed with an experienced anæsthetist. Conditions that are less urgent, but in which operation may be highly desirable, must wait until the cardiac condition has been properly assessed and the patient prepared for the unwonted stress. *There are also circumstances in which the cardiac condition is worsened* by some disability which can be dealt with by operation. Chronic septic absorption from the biliary tract is a good illustration, and there are many cardiac disturbances which are greatly improved by an operation on the gall-bladder. Renal insufficiency associated with enlarged prostate furnishes another example, for in these cases bladder drainage often proves beneficial to the heart.

High blood-pressure is often temporarily improved by some necessary operation, especially if it is accompanied by a reasonable amount of blood loss. The treatment of a septic focus, or of renal embarrassment by bladder drainage in cases of enlarged prostate, often does much good. But operations that are entirely optional should be avoided in marked hypertension with cardiac or renal damage, unless there is likely to be some great compensating advantage.

Pulmonary tuberculosis which is not itself the object of surgical intervention.—Acute emergencies must be dealt with by life-saving interventions, and it is then largely a question of selecting the form of anæsthesia which is least likely to be harmful to the pulmonary condition. Sometimes duodenal ulcer or pyloric stenosis may seriously interfere with that proper nutrition which is so necessary to combat phthisis. In these circumstances gastro-enterostomy or gastrectomy may be carried out with great advantage. Intestinal obstructive symptoms also demand surgical intervention, and a short-circuiting operation or even intestinal resection may be required But the surgeon should be very suspicious of diarrhœa as a symptom, for it nearly always means tuberculous enteritis and is of grave prognosis. In these interventions local or perhaps spinal anæthesia should be employed. It is perfectly true that many patients with quiescent tuberculous lesions tolerate general anæsthesia quite well, but should a lesion be lighted up the surgeon will feel responsible, and in any event convalescence is apt to be greatly prolonged.

Among **other pulmonary conditions** bronchiectasis is important. When the condition is in a dry stage a general anæsthetic may be well

tolerated, but in the active phase with copious sputum only local anaesthesia is permissible. Whenever possible, interference should be postponed until the bronchi can be drained by postural and other measures and the full benefit of penicillin therapy can be obtained. Patients who suffer from asthma often seem to be temporarily improved by general anaesthesia, but this fortunate result cannot be relied upon, so that local anaesthesia should be employed whenever it will suffice. In chronic respiratory diseases, operations that can be safely postponed are better dealt with during the summer months or at least at such a time as the patient recognizes from previous experience that the chest condition is likely to be least troublesome.

Haemophilia.—Only really urgent life-saving operations are permissible and they should be carried out immediately after blood transfusion. The smallest incision and the fewest needle punctures that will suffice should be employed, and meticulous care must be taken to secure all bleeding points. Dead spaces should be obliterated by well applied pressure. Among styptics, snake venom (Russell's viper) in a dilution of 1:10,000 used locally, is said to be most effective and free from harmful effects. Thrombin, becoming more readily available and most effective if properly used, should not be forgotten.*

Insane patients usually become quite docile in acute surgical emergency, and there is no reason why necessary life-saving operations should not be carried out successfully. In an extensive experience, the writer does not recall a single case in which there were unusual difficulties in aftercare. Apart from emergencies, conditions threatening life or causing pain or grave disability should be dealt with by operation. No ethical considerations should deter the surgeon from giving such relief as his art can afford. The probable progress of the mental disease will naturally be taken into consideration, but that is a matter for the psychiatrist rather than the surgeon.

Pregnancy with abdominal emergencies is an indication for early intervention rather than delay. Appendicitis treated by operation before peritoneal complications arise or become serious, does very well indeed and, even if drainage is necessary, pregnancy is seldom interrupted. Operations of election that can be postponed should be allowed to wait until after delivery. Malignant disease of the breast runs a very rapid course during pregnancy and its presence raises very serious questions. Unless there are very special reasons against it, the pregnancy should usually be terminated and the complete radical breast operation carried out.

Military surgery.—The scope of this work as a guide to the *operations of surgery* does not embrace the general management of gunshot wounds, but in many of the sections there are references to matters of importance in military practice. The following notes may provide some guidance to the primary treatment of war wounds. *It is*

* Grey Turner, *Lancet*, July 31st, 1943

a contra-indication, but it adds a decided risk to operation. Those forms which are readily diagnosed and which can be compensated by appropriate management cause less anxiety than coronary disease, where there is so often degenerative change in the heart muscle. Even in the latter condition really necessary operations may be undertaken, especially since the relief afforded often benefits the cardiac mischief. Conditions which threaten life, such as strangulated hernia, perforation of a viscus, or acute appendicitis, must be dealt with by the simplest possible measures. Local anæsthesia, combined if necessary with a minimum of gas and oxygen, will suffice for most such operations. It is best if the appropriate method can be discussed with an experienced anæsthetist. Conditions that are less urgent, but in which operation may be highly desirable, must wait until the cardiac condition has been properly assessed and the patient prepared for the unwonted stress. There are also circumstances in which the cardiac condition is worsened by some disability which can be dealt with by operation. Chronic septic absorption from the biliary tract is a good illustration, and there are many cardiac disturbances which are greatly improved by an operation on the gall-bladder. Renal insufficiency associated with enlarged prostate furnishes another example, for in these cases bladder drainage often proves beneficial to the heart.

High blood-pressure is often temporarily improved by some necessary operation, especially if it is accompanied by a reasonable amount of blood loss. The treatment of a septic focus, or of renal embarrassment by bladder drainage in cases of enlarged prostate, often does much good. But operations that are entirely optional should be avoided in marked hypertension with cardiac or renal damage, unless there is likely to be some great compensating advantage.

Pulmonary tuberculosis which is not itself the object of surgical intervention.—Acute emergencies must be dealt with by life-saving interventions, and it is then largely a question of selecting the form of anæsthesia which is least likely to be harmful to the pulmonary condition. Sometimes duodenal ulcer or pyloric stenosis may seriously interfere with that proper nutrition which is so necessary to combat phthisis. In these circumstances gastro-enterostomy or gastrectomy may be carried out with great advantage Intestinal obstructive symptoms also demand surgical intervention, and a short-circuiting operation or even intestinal resection may be required But the surgeon should be very suspicious of diarrhœa as a symptom, for it nearly always means tuberculous enteritis and is of grave prognosis. In these interventions local or perhaps spinal anæthesia should be employed. It is perfectly true that many patients with quiescent tuberculous lesions tolerate general anæsthesia quite well, but should a lesion be lighted up the surgeon will feel responsible, and in any event convalescence is apt to be greatly prolonged

Among **other pulmonary conditions** bronchiectasis is important When the condition is in a dry stage a general anæsthetic may be well

tolerated, but in the active phase with copious sputum only local anæsthesia is permissible. Whenever possible, interference should be postponed until the bronchi can be drained by postural and other measures and the full benefit of penicillin therapy can be obtained. Patients who suffer from asthma often seem to be temporarily improved by general anæsthesia, but this fortunate result cannot be relied upon, so that local anæsthesia should be employed whenever it will suffice. In chronic respiratory diseases, operations that can be safely postponed are better dealt with during the summer months or at least at such a time as the patient recognizes from previous experience that the chest condition is likely to be least troublesome.

Hæmophilia.—Only really urgent life-saving operations are permissible and they should be carried out immediately after blood transfusion. The smallest incisions and the fewest needle punctures that will suffice should be employed, and punctilious care must be taken to secure all bleeding points. Dead spaces should be obliterated by well applied pressure. Among styptics, snake venom (Russell's viper) of a dilution of 1/10,000 used locally, is said to be most effective and free from harmful effects. Turpentine, being more readily obtainable and most effective if properly used, should not be forgotten.*

Insane patients usually become quite docile in acute surgical emergency, and there is no reason why necessary life-saving operations should not be carried out successfully. In an extensive experience, the writer does not recall a single case in which there were unusual difficulties in after-care. Apart from emergencies, conditions threatening life or causing pain or grave disability should be dealt with by operation. No ethical considerations should deter the surgeon from giving such relief as his art can afford. The probable progress of the mental disease will naturally be taken into consideration, but that is a matter for the psychiatrist rather than the surgeon.

Pregnancy with abdominal emergencies is an indication for early intervention rather than delay. Appendicitis treated by operation before peritoneal complications arise or become serious, does very well indeed and, even if drainage is necessary, pregnancy is seldom interrupted. Operations of election that can be postponed should be allowed to wait until after delivery. Malignant disease of the breast runs a very rapid course during pregnancy and its presence raises very serious questions. Unless there are very special reasons against it, the pregnancy should usually be terminated and the complete radical breast operation carried out.

Military surgery.—The scope of this work as a guide to the operations of surgery does not embrace the general management of gunshot wounds, but in many of the sections there are references to matters of importance in military practice. The following notes may provide some guidance to the primary treatment of war wounds. *It is*

* Grey Turner, *Lancet*, July 31st, 1915.

essential to recognize that those general principles which afford guidance in civilian surgery also govern the management of injuries met with in warfare, and the more closely such principles can be observed the better the results. But whatever our aims and our plans for the treatment of those wounded in battle, the first and often the greatest problem is the question of transportation, so that casualties may be brought to the surgeons working in suitably equipped hospitals within a reasonable time. In the more or less static warfare which prevailed during a great part of the campaigns of 1914–18 this was difficult enough, but in certain areas it was eventually possible to arrange for treatment in the casualty clearing stations in from 6 to 10 hours. In the 1939–45 war the same problems applied to civilian casualties from air-raids as well as to troops on the battle fields. In the intense mobile warfare characteristic of these present days the difficulties may be extreme. When the surgeon can be taken to the wounded man the prospect would appear better, but this has usually only been possible in such circumstances that little in the way of surgical intervention can be carried out. Transport by air may often be the only solution*; it has the advantage that in short flying time wounded may be taken to special centres equipped for dealing with different injuries, i.e. chest and head centres in particular.

Until such time as hospital treatment is possible, the main indications are to arrest hæmorrhage, to treat shock and to prevent infection. There are many different varieties of war wounds, from the comparatively simple through-and-through bullet-wound to the very severe injuries produced by shell fragments. The injuries are often multiple, and several different types of wound may be found in the same patient. The local injury may extend far beyond the original site, and in some cases there is a special tendency to disruption of the surrounding parts This particularly affects the muscles, which are found greyish, almost avascular and without the power to contract on mechanical stimulation. The condition is sometimes spoken as of " muscle stupor " Such tissue provides an excellent culture medium for anærobic organisms. Another feature of these severe wounds is the tendency to reactionary œdema, which causes much swelling, with tension beneath the deep fascia and consequent interference with circulation and with drainage. Though so many of these wounds are contaminated with organisms at the outset, they are not actively infected until the organisms begin to multiply in the tissues. No stated time can be given at which this takes place, but for the most part it is not likely to be established until from 6 to 12 hours after the wound has been inflicted. There are also types of injury, especially to the viscera, which are due to compression or blast from high explosives. The location of the wound may bear little relation to the injury inflicted as, for instance, wounds of the buttocks, which are notoriously dangerous, for they are so often complicated by serious abdominal lesions

* Moreover it may be a very happy one as has been shown by the use of helicopters in the recent campaign in Korea where the mortality from war wounds was still further reduced below that of the second world war (L C R)

Apart from the type of wound, the general condition of the patient must be taken into consideration, for the effects of blood loss and shock are so important. With the exception of clean through-and-through or traversing bullet wounds, *war wounds in general require such a complete toilet as to amount to a surgical operation*, and it is on the care and thoroughness with which this can be carried out that the ultimate result largely depends. The main object of the intervention is to anticipate sepsis by excising all torn and devitalized tissues and to expose and cleanse every part of the depths of the wound, but, to be successful, this intervention must be undertaken before organisms have begun to multiply in the tissues. To carry out this wound toilet properly the part must be anæsthetized and in British practice general anæsthesia is nearly always employed. With the help of all the arrangements for a major operation, the wound must be enlarged, so that every part of its depths can be explored. This is combined with the excision of the contused and lacerated tissue and to that extent it is a wound excision, but it is not necessary to do a formal *en bloc* excision in every case or to remove any great amount of the tissue surrounding the wound. While it may be expedient completely to excise the whole of the damaged tissues in the smaller wounds, to attempt such a complete excision in the larger wounds is likely to lead to an unnecessary and harmful amount of additional traumatism. But in these larger wounds bruised and lacerated skin, torn and frayed fascia, separated muscle or muscle without life must all be removed with scalpel and scissors until healthy-looking and freely-bleeding tissues are exposed. For the skin a margin of about a quarter of an inch around the damaged edges will suffice. Blood clot, debris and easily-accessible foreign bodies should be removed and bleeding vessels secured. It is a great help in the examination of the depths of the wound, and an incentive to healing, to have all bleeding arrested, and the aim must always be to do this by ligature applied to the bleeding site. For these purposes the depths of the wound must be inspected and retractors are invaluable. The thorough exploration provides an opportunity of examining the extent of the damage to structures like muscles, tendons, arteries, nerves and bones. If the wound is a clean one and is treated within about six hours of infliction, immediate repair of the soft parts may be attempted; otherwise it is usually considered better to defer nerve and tendon suture for secondary operations to be carried out after the wound has soundly healed. The thorough exploration and exposure of the depths of the wound also provide an opportunity for treating its surfaces with some anti-bacterial substance, the most popular at present being preparations of the sulphanilamide group and the antibiotics such as penicillin and chloramphenicol. As yet there is no general agreement on their utility, but it can be emphatically stated that the neglect of proper wound toilet cannot be compensated for by even the most liberal use of the sulphonamides or penicillin.

After the toilet of the wound has been adequately carried out, it

is the present practice to leave it entirely open with or without light packing with petroleum jelly gauze or tulle gras, and fixation, in the case of the limbs, usually by plaster, taking great care that it is not too tightly applied. Firm packing is sometimes used for the arrest of hæmorrhage, but this should be avoided whenever possible as it interferes with the circulation and with drainage, causes pain and usually requires an anæsthetic for its removal. Drainage is probably most efficient when the gauze is thickly smeared with vaseline, but when a pack is used to arrest hæmorrhage it should either be plain dry gauze or gauze dusted with sulphonamide and penicillin powder. Petroleum jelly packs are safely extruded during healing. At the moment, primary wound suture is out of favour and to be avoided as it may be disastrous when transport to other hospitals is taking place, and the patient cannot be kept under continuous observation by those who have carried out the initial treatment. There is little objection to secondary suture when it is likely to facilitate healing, but in practice it is seldom necessary. If there are already signs of infection, such as are likely to be in evidence after 18 to 24 hours, it is too late for a complete wound toilet and all that can then be done is to open up the wound, so that drainage may be unimpeded, and to remove loose foreign bodies and débris. But the use of sulpha drugs and antibiotics *has completely changed the outlook that even in the presence of* infection, devitalized tissue may be excised. If there is much swelling and œdema, free incision of the skin and the restraining deep fascia is most important and counter-incisions may be valuable.

Many workers, notably Trueta, have advocated *immobilization as an adjunct to wound healing.* The complete rest deters the absorption of organisms and toxins and also encourages healing. To secure immobilization, the limb is commonly encased in plaster of Paris, which is applied over the dressings or direct to the skin, the latter being smeared with vaseline to prevent the plaster adhering to the hairs; windows should be avoided. If all goes well, the plaster may be left in position for from 2 to 6 weeks, when the wounds are usually found to be granulating satisfactorily. During most of this period the patient should be kept at rest with the affected limb horizontal. Healing often occurs with surprising speed, but there can be no absolute certainty that this will follow without infection, and for that reason the wounded should be under skilled supervision for at least four days after application of the plaster. Inflammatory swelling beneath the unyielding plaster may lead to the most serious consequences, such as gangrene, which only prompt removal of the plaster will arrest or mitigate This plaster method has been very generally adopted and, though in slighter wounds it is not essential, in severe deep wounds *there can be no doubt of the great benefit of immobilization by this* means

In fractures or wounds of bone it is necessary to take care that the bones are in proper alignment. If the site is explored, loose bone fragments should not be hastily removed but should be moulded

into position. Even if such fragments subsequently necrose, in the meantime they furnish the best stimulus to repair and bone formation. Immobilization must be secured as soon as possible, as the best means of reducing shock, and in the lower extremity it must be made adequate by including the joints above and below the site. Plaster of Paris is convenient and satisfactorily excludes sepsis, but the important principle is *the rest to the parts provided by immobilization*, however this is secured. The Thomas's splint or even wooden splints, if intelligently applied, may be quite satisfactory. Plaster slabs fashioned for two surfaces of a limb and kept in position by a few turns of plaster bandage have the advantage that they can very readily be removed by the surgeon or his assistant using ordinary scissors. To get the best use from plaster the technique of its application must be thoroughly understood. Fixation by plates or bone grafting should not be employed in recent war wounds.

When *amputation* is called for, the principles observed in civil life can usually be employed, and ablation of a limb by the guillotine method is seldom required. Even in the worst case it is usually possible to make short skin flaps, and these may be left without sutures or loosely drawn together over gauze, so that when risk of infection has disappeared secondary suture may be carried out. Recent amputation cases travel badly, and it has been found that the support of a plaster cap over the stump is helpful.

Wounds involving the body cavities usually require operation or other attention, e.g. aspiration of a hæmothorax, and a nice judgment must decide those that have the best chance if left alone—as, for instance, in some of the cases where it is probable that the liver is the only organ involved. Where there is great *laceration of the soft parts about the face*, neck or the flexures, crippling deformity is frequently a sequel calling for much ingenuity in plastic repair. Whenever circumstances permit, great care should be taken in the primary treatment of these injuries with a view to the prevention of deformity, but when there has been great loss of tissue it is a mistake to attempt plastic repair as a first intervention. The surgeon must endeavour to prevent loss of tissue from necrosis, often the result of tension following ill-considered attempts to draw widely-separated edges together, and also to prevent unnecessary retraction of wound edges. Above all else, sepsis must be avoided. In slow-healing granulating wounds skin grafting is most helpful.

On general principles *foreign bodies should be removed* whenever wounds are explored and the foreign bodies are easily accessible. But this rule must be applied with discretion, for very small foreign bodies, deeply imbedded in muscular parts, or multiple small foreign bodies are best left alone. It does not follow that they will prove harmless, but they are better left undisturbed unless symptoms arise. There must also be reservations about missiles in the brain, the lungs or the abdominal viscera, all of which require special consideration. In any case missiles that cannot be seen in wounds or felt in the soft parts

must be carefully localized by X-ray before attempts to remove them are undertaken. At operation the modern probe metal detector should be part of the surgeon's equipment.

The principle of short circuiting can often be usefully applied in military surgery: colostomy for wounds of the colon or rectum, cystostomy when the bladder or urethra are injured, or gastrostomy for severe wounds about the floor of the mouth or pharynx.

CHAPTER I

CONSERVATIVE TREATMENT IN NON-RESPIRATORY TUBERCULOSIS

By E. STANLEY EVANS, C.B.E.

SURGICAL tuberculosis can no longer be regarded as applying to tuberculosis of bones and joints and extrapulmonary lesions, for the principle of surgically induced rest and immobilization is now used to a greater extent in the treatment of pulmonary tuberculosis, and the adoption of the self-explanatory terms respiratory and non-respiratory tuberculosis is supported. The patient suffering from a non-respiratory tuberculous lesion is a tuberculous patient with a local manifestation of the disease, and general treatment by conservative as opposed to operative methods is essential in the early stages when a tuberculous bacillæmia is present, to enable the patient successfully to combat the disease. Conservative treatment does not connote masterly inactivity, but a combination of general and local treatment, with the object of achieving quiescence of the disease. Although the value of streptomycin, para-amino salicylic acid (P.A.S.), and Calciferol in the treatment of non-respiratory tuberculosis has not yet been clearly defined, there is little doubt that they will exert a profound effect on the natural history and evolution of the disease, and shorten the period of general treatment necessary. A long view is essential in tuberculosis and however attractive the possibilities may be, the well-tried principles of conservative orthopædic treatment must not be lightly discarded. In the light of our present knowledge, the use of antibiotics is reasonable in the bacillæmic stage and in order to render surgical intervention safer in an earlier quiescent stage.

Conservative treatment can conveniently be considered under the following headings:—General, Adjuvant and Local.

GENERAL TREATMENT

All those therapeutic measures which improve the general health of the patient, and thereby increase resistance to tuberculosis, are of importance and demand consideration of rest and recumbency, climate and locality, diet, occupation, tuberculin and antibiotics. It must again be stressed that the local lesion is associated with a primary tuberculous focus and with a tuberculous bacillæmia. Throughout, good nursing is essential.

Rest and recumbency.—Rest in bed is essential in the early treatment of a patient suffering from a tuberculous lesion, in order to husband his resources and strength during the bacillæmic stage of the

disease. Only in this way can the general condition of the patient be accurately assessed so far as his response is concerned. Even when the local lesion does not appear to demand almost complete rest, and when, from the orthopædic point of view, it can be treated in an ambulant patient, the same principle must be observed. The patient suffering from tuberculosis of a joint or bone of the upper limb, for example tuberculous wrist or dactylitis, must be put at rest in bed during the initial stages, for the local lesion is associated with an active focus elsewhere in the body, such as tuberculous mediastinal or mesenteric adenitis. When the general condition of the patient shows obvious improvement, and there is no longer secondary anæmia or pyrexia, when the appetite improves, and weight becomes constant or increases, when the blood sedimentation rate falls to within normal limits, the local lesion may be treated on its own orthopædic merits. In tuberculous lesions of the upper limb this may mean a period of rest in bed for two or three months, or more, depending on the response of the patient, and may be followed by ambulant treatment with appropriate splintage, in optimum open air conditions. No tuberculous lesion can be lightly regarded in the early stages, nor until the patient's general response becomes apparently satisfactory. Local operative treatment is inadvisable in the bacillæmic phase of the disease, but if it becomes necessary should be carried out only under adequate cover with streptomycin and P A.S. Continued bed rest forms an integral part of the treatment of those patients whose lesions demand removal of weight bearing and prolonged immobilization for many months, and this is particularly true of tuberculosis of the spine, and of the bones and joints of the lower limb.

Climate and locality.—Experience has demonstrated clearly that one of the most important factors in general treatment is that the patient shall be nursed in suitable open air conditions Carefully planned and graduated exposure of the body, accompanied by skilled nursing, improves the appetite and raises the metabolic rate by accelerating all the processes of metabolism Some respond better to treatment in the country, provided the climate is not too humid, and this generally implies a sandy or chalky subsoil as in many long-stay orthopædic hospitals in this country; others respond to treatment at higher altitudes such as at Leysin, and yet others to the more stimulating seaside conditions where marine therapy can be carried out. It is sometimes found that a patient treated at a country hospital, as at Alton, improves markedly for a time, and then responds more rapidly when transferred to a seaside branch such as Hayling Island. Others, particularly fair-haired, pale children, under the age of five, respond unfavourably to marine therapy, and when nursed under such conditions develop pyrexia, lose appetite and weight, and exhibit more activity in the local lesion. No hard and fast rule can be laid down as to the location for treatment, as each patient must be judged on his merits and therapeutic response.

Diet.—In broad outline one of the essential features in the pathology of the active tuberculous lesion in bone is osteoporosis and decalcification, whereas the healing phase of all forms of tuberculosis is associated with calcification. Consequently in the past it became almost a ritual to provide extra milk, butter, cream, cod liver oil and malt, and various other forms of Vitamin D. It is now generally accepted that a generous and varied diet, with extra milk and fresh vegetables and fruit, provides all the essential food requisites in general, and an adequacy of calcium salts and Vitamins C and D in particular. Greater stress is laid on the need for providing all the essential amino acids and proteins, particularly in the growing child, and on the fact that an excess of fats is unnecessary, and must be avoided in children subject to attacks of ketosis. An abundance of fluid is essential, and fluid intake and output should be charted in all patients treated by prolonged recumbency, for maintenance of fluid balance is probably the chief factor in preventing urinary lithiasis in such cases.

Occupation.—Patients treated for prolonged periods in hospital must be kept occupied physically and mentally in order to avoid the incidental evils of prolonged hospitalization. Children must be nursed in long-stay open air orthopædic hospital schools where education can be provided during the course of treatment. Unless contra-indicated during the early stages of disease, or when otherwise physically unfit, children should be given four hours' teaching daily, so that their general standard of education shall not suffer unduly. Hospital troops of Boy Scouts and Girl Guides help to maintain contact with the outside world. Adults should be given opportunities for preparatory training for various occupations, crafts and professions, whilst for all patients, lectures, cinema shows, art classes, wireless entertainments, and all reasonable outside contacts should be provided in order to minimize the undesirable mental, psychological and social effects of prolonged treatment in hospital.

Tuberculin.—No account of the principles of general treatment would be complete unless accompanied by the statement that orthodox tuberculin therapy has now no place in the treatment of non-respiratory tuberculosis; it has, however, been suggested, but not proven, that the stimulation and reaction produced by tuberculin may enable general treatment by streptomycin and P.A.S. to be more effective.

Antibiotics.—The value of systemic streptomycin administered in the early active stages of disease, to enable the patient to resist and overcome the tuberculous bacillæmia, and to prevent the development of further local lesions, would be inestimable but for the toxic effects that may follow, and the fact that streptomycin resistant strains of the tubercle bacillus are likely to emerge. It is now generally agreed that these dangers may be minimized by giving adequate but not excessive amounts of streptomycin and by using a combination of streptomycin and para-amino-salicylic acid. In the adult the administration of

disease. Only in this way can the general condition of the patient be accurately assessed so far as his response is concerned. Even when the local lesion does not appear to demand almost complete rest, and when, from the orthopædic point of view, it can be treated in an ambulant patient, the same principle must be observed. The patient suffering from tuberculosis of a joint or bone of the upper limb, for example tuberculous wrist or dactylitis, must be put at rest in bed during the initial stages, for the local lesion is associated with an active focus elsewhere in the body, such as tuberculous mediastinal or mesenteric adenitis. When the general condition of the patient shows obvious improvement, and there is no longer secondary anæmia or pyrexia, when the appetite improves, and weight becomes constant or increases, when the blood sedimentation rate falls to within normal limits, the local lesion may be treated on its own orthopædic merits. In tuberculous lesions of the upper limb this may mean a period of rest in bed for two or three months, or more, depending on the response of the patient, and may be followed by ambulant treatment with appropriate splintage, in optimum open air conditions. No tuberculous lesion can be lightly regarded in the early stages, nor until the patient's general response becomes apparently satisfactory. Local operative treatment is inadvisable in the bacillæmic phase of the disease, but if it becomes necessary should be carried out only under adequate cover with streptomycin and P.A.S. Continued bed rest forms an integral part of the treatment of those patients whose lesions demand removal of weight bearing and prolonged immobilization for many months, and this is particularly true of tuberculosis of the spine, and of the bones and joints of the lower limb.

Climate and locality.—Experience has demonstrated clearly that one of the most important factors in general treatment is that the patient shall be nursed in suitable open air conditions. Carefully planned and graduated exposure of the body, accompanied by skilled nursing, improves the appetite and raises the metabolic rate by accelerating all the processes of metabolism Some respond better to treatment in the country, provided the climate is not too humid, and this generally implies a sandy or chalky subsoil as in many long-stay orthopædic hospitals in this country; others respond to treatment at higher altitudes such as at Leysin, and yet others to the more stimulating seaside conditions where marine therapy can be carried out. It is sometimes found that a patient treated at a country hospital, as at Alton, improves markedly for a time, and then responds more rapidly when transferred to a seaside branch such as Hayling Island. Others, particularly fair-haired, pale children, under the age of five, respond unfavourably to marine therapy, and when nursed under such conditions develop pyrexia, lose appetite and weight, and exhibit more activity in the local lesion No hard and fast rule can be laid down as to the location for treatment, as each patient must be judged on his merits and therapeutic response.

Diet.—In broad outline one of the essential features in the pathology of the active tuberculous lesion in bone is osteoporosis and decalcification, whereas the healing phase of all forms of tuberculosis is associated with calcification. Consequently in the past it became almost a ritual to provide extra milk, butter, cream, cod liver oil and malt, and various other forms of Vitamin D. It is now generally accepted that a generous and varied diet, with extra milk and fresh vegetables and fruit, provides all the essential food requisites in general, and an adequacy of calcium salts and Vitamins C and D in particular. Greater stress is laid on the need for providing all the essential amino acids and proteins, particularly in the growing child, and on the fact that an excess of fats is unnecessary, and must be avoided in children subject to attacks of ketosis. An abundance of fluid is essential, and fluid intake and output should be charted in all patients treated by prolonged recumbency, for maintenance of fluid balance is probably the chief factor in preventing urinary lithiasis in such cases.

Occupation.—Patients treated for prolonged periods in hospital must be kept occupied physically and mentally in order to avoid the incidental evils of prolonged hospitalization. Children must be nursed in long-stay open air orthopædic hospital schools where education can be provided during the course of treatment. Unless contra-indicated during the early stages of disease, or when otherwise physically unfit, children should be given four hours' teaching daily, so that their general standard of education shall not suffer unduly. Hospital troops of Boy Scouts and Girl Guides help to maintain contact with the outside world. Adults should be given opportunities for preparatory training for various occupations, crafts and professions, whilst for all patients, lectures, cinema shows, art classes, wireless entertainments, and all reasonable outside contacts should be provided in order to minimize the undesirable mental, psychological and social effects of prolonged treatment in hospital.

Tuberculin.—No account of the principles of general treatment would be complete unless accompanied by the statement that orthodox tuberculin therapy has now no place in the treatment of non-respiratory tuberculosis; it has, however, been suggested, but not proven, that the stimulation and reaction produced by tuberculin may enable general treatment by streptomycin and P.A.S. to be more effective.

Antibiotics.—The value of systemic streptomycin administered in the early active stages of disease, to enable the patient to resist and overcome the tuberculous bacillæmia, and to prevent the development of further local lesions, would be inestimable but for the toxic effects that may follow, and the fact that streptomycin resistant strains of the tubercle bacillus are likely to emerge. It is now generally agreed that these dangers may be minimized by giving adequate but not excessive amounts of streptomycin and by using a combination of streptomycin and para-amino-salicylic acid. In the adult the administration of

disease. Only in this way can the general condition of the patient be accurately assessed so far as his response is concerned. Even when the local lesion does not appear to demand almost complete rest, and when, from the orthopædic point of view, it can be treated in an ambulant patient, the same principle must be observed. The patient suffering from tuberculosis of a joint or bone of the upper limb, for example tuberculous wrist or dactylitis, must be put at rest in bed during the initial stages, for the local lesion is associated with an active focus elsewhere in the body, such as tuberculous mediastinal or mesenteric adenitis. When the general condition of the patient shows obvious improvement, and there is no longer secondary anæmia or pyrexia, when the appetite improves, and weight becomes constant or increases, when the blood sedimentation rate falls to within normal limits, the local lesion may be treated on its own orthopædic merits. In tuberculous lesions of the upper limb this may mean a period of rest in bed for two or three months, or more, depending on the response of the patient, and may be followed by ambulant treatment with appropriate splintage, in optimum open air conditions No tuberculous lesion can be lightly regarded in the early stages, nor until the patient's general response becomes apparently satisfactory. Local operative treatment is inadvisable in the bacillæmic phase of the disease, but if it becomes necessary should be carried out only under adequate cover with streptomycin and P.A.S. Continued bed rest forms an integral part of the treatment of those patients whose lesions demand removal of weight bearing and prolonged immobilization for many months, and this is particularly true of tuberculosis of the spine, and of the bones and joints of the lower limb.

Climate and locality.—Experience has demonstrated clearly that one of the most important factors in general treatment is that the patient shall be nursed in suitable open air conditions. Carefully planned and graduated exposure of the body, accompanied by skilled nursing, improves the appetite and raises the metabolic rate by accelerating all the processes of metabolism. Some respond better to treatment in the country, provided the climate is not too humid, and this generally implies a sandy or chalky subsoil as in many long-stay orthopædic hospitals in this country; others respond to treatment at higher altitudes such as at Leysin, and yet others to the more stimulating seaside conditions where marine therapy can be carried out. It is sometimes found that a patient treated at a country hospital, as at Alton, improves markedly for a time, and then responds more rapidly when transferred to a seaside branch such as Hayling Island. Others, particularly fair-haired, pale children, under the age of five, respond unfavourably to marine therapy, and when nursed under such conditions develop pyrexia, lose appetite and weight, and exhibit more activity in the local lesion. No hard and fast rule can be laid down as to the location for treatment, as each patient must be judged on his merits and therapeutic response.

Diet.—In broad outline one of the essential features in the pathology of the active tuberculous lesion in bone is osteoporosis and decalcification, whereas the healing phase of all forms of tuberculosis is associated with calcification. Consequently in the past it became almost a ritual to provide extra milk, butter, cream, cod liver oil and malt, and various other forms of Vitamin D. It is now generally accepted that a generous and varied diet, with extra milk and fresh vegetables and fruit, provides all the essential food requisites in general, and an adequacy of calcium salts and Vitamins C and D in particular. Greater stress is laid on the need for providing all the essential amino acids and proteins, particularly in the growing child, and on the fact that an excess of fats is unnecessary, and must be avoided in children subject to attacks of ketosis. An abundance of fluid is essential, and fluid intake and output should be charted in all patients treated by prolonged recumbency, for maintenance of fluid balance is probably the chief factor in preventing urinary lithiasis in such cases.

Occupation.—Patients treated for prolonged periods in hospital must be kept occupied physically and mentally in order to avoid the incidental evils of prolonged hospitalization. Children must be nursed in long-stay open air orthopædic hospital schools where education can be provided during the course of treatment. Unless contra-indicated during the early stages of disease, or when otherwise physically unfit, children should be given four hours' teaching daily, so that their general standard of education shall not suffer unduly. Hospital troops of Boy Scouts and Girl Guides help to maintain contact with the outside world. Adults should be given opportunities for preparatory training for various occupations, crafts and professions, whilst for all patients, lectures, cinema shows, art classes, wireless entertainments, and all reasonable outside contacts should be provided in order to minimize the undesirable mental, psychological and social effects of prolonged treatment in hospital.

Tuberculin.—No account of the principles of general treatment would be complete unless accompanied by the statement that orthodox tuberculin therapy has now no place in the treatment of non-respiratory tuberculosis; it has, however, been suggested, but not proven, that the stimulation and reaction produced by tuberculin may enable general treatment by streptomycin and P.A.S. to be more effective.

Antibiotics.—The value of systemic streptomycin administered in the early active stages of disease, to enable the patient to resist and overcome the tuberculous bacillæmia, and to prevent the development of further local lesions, would be inestimable but for the toxic effects that may follow, and the fact that streptomycin resistant strains of the tubercle bacillus are likely to emerge. It is now generally agreed that these dangers may be minimized by giving adequate but not excessive amounts of streptomycin and by using a combination of streptomycin and para-amino-salicylic acid. In the adult the administration of

1 gm. of streptomycin and 20 gm. of P.A.S. daily for an initial period of three months may be carried out, provided the diagnosis of tuberculosis has been confirmed beyond reasonable doubt Careful assessment of all the available evidence afforded by the personal, family and milk history, the clinical examination, the X-ray appearances and a positive Mantoux test, is essential in arriving at a tentative diagnosis of a non-respiratory tuberculous lesion. Where possible the diagnosis should be confirmed by the histology and culture of material removed at lymphatic gland or joint biopsy. When doubt as to the diagnosis exists, it is probable that this form of therapy should be withheld

In addition to the substances already mentioned, isonicotinic acid hydrazide (I.N.H.), or one of its derivatives, is also available both for systemic and local therapy. If I.N.H. is used alone resistant strains of the tubercle bacillus emerge rapidly, and it appears that it should always be administered in combination with either streptomycin or P.A.S. Bearing in mind the chronicity of the disease, and the possibility of further spread and renewed activity, it may be advisable to use only two of the three groups of antibiotics initially, so that the other, preferably streptomycin, is available subsequently.

The value of chemotherapy in the treatment of non-respiratory tuberculosis has not yet been fully assessed, but antibiotics may be used to:—

(1) Control the general infection and prevent other local lesions in the initial bacillæmic stage of the disease.

(2) Secure moveable joints instead of fibrous ankylosis. This object cannot be obtained when the blood supply to the affected joint is diminished by tuberculous endarteritis, and considerable destruction and caseation is present, but only in the early hyperæmic stages when it may be predominantly synovial in type.

(3) Provide operative cover and thereby prevent local spread of disease and general dissemination. Operative procedures formerly regarded as inadvisable and dangerous may now be performed at a relatively early stage of disease, and with far less danger of complications.

(4) Treat the affected joint by repeated injections or by local administration when joint biopsy, partial synovectomy, or the eradication of a tuberculous focus is carried out.

(5) Shorten the duration of recumbent and hospital in-patient treatment, as this economic factor is of great importance quite apart from the psychological effect on the patient.

The value of chemotherapy in the treatment of sinuses associated with tuberculous lesions is discussed later.

ADJUVANT TREATMENT

Heliotherapy and the technique of general sun treatment.— The sun emits radiations of varying wave-lengths, having certain

precise characteristics. When visible light is passed through a prism it is split into its component parts to give a spectrum consisting of violet light of shorter, to red rays of longer wave-length, and other component parts of intermediate wave-lengths. Ultra-violet rays are of shorter wave-length than visible violet light, and radiations of longer wave-lengths than visible red light consist of infra-red or heat radiations. Ultra-violet light is beneficial, and its effect is seen in the pigment cells of the skin when pigmentation occurs and ergosterol or Vitamin D stored in the pigment cells is activated by irradiation. An excess of ultra-violet light produces erythema and blistering. Infra-red rays or heat radiations are harmful, and if excessive exposure occurs can be dangerous. Heliotherapy therefore aims at securing the greatest response to ultra-violet radiation, whilst avoiding as far as possible the harmful infra-red rays. Formerly—about fifteen years

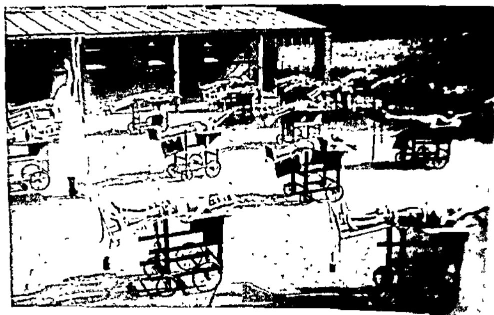


Fig. 1.—Patients undergoing heliotherapy and general exercises

ago—patients were exposed during the day, and were protected to some extent by sun glasses, sun hats and shades, from the adverse effects of intense light therapy. They became deeply pigmented, assuming a dark brown colour if good pigmenters—and were dehydrated by sensible and insensible perspiration, so that the skin became loose and inelastic, and subcutaneous fat became ... The modern technique of heliotherapy is to treat patients ... air overnight except in inclement weather, and to ... until about 10.30 a.m. in bright sunny weather. They are then ... under cover when the sun is high in the heavens in the ... and moved out on to the terrace again about 3.30 p.m. ... of the sun are less intense. Under these circumstances ... become dehydrated, subcutaneous tissue is not lost ... become inelastic, and deep pigmentation is not se...

to expose the body gradually even under such circumstances, as otherwise excessive response and erythema may occur. Such a régime of heliotherapy results in the greatest response and enables open air treatment to be carried out comfortably (Fig. 1). The complication of urinary lithiasis is avoided by the adequate administration of fluids.

Actinotherapy or artificial light treatment.—In view of the uncertain and unpredictable nature of the climate in this country, it is impossible to carry out a scientific and precise programme of heliotherapy even during the summer months, and much will depend on the experience and skill of the ward sister responsible for carrying out such treatment. During the winter months in particular, heliotherapy can be replaced by artificial light treatment which can be graduated more or less scientifically In actinotherapy, treatment by ultra-violet light is provided by using various lamps, particularly carbon arc lamps. The intensity of ultra-violet light varies inversely as the square of the distance of the patient from the lamp, and directly as the length of exposure. Generally, patients are treated at fixed distances from the lamp, and the time of exposure is gradually increased as the patient and the pigment cells in the skin respond. Plain or cored carbons of various sizes and amperage are used, and sub-erythema exposures given; commencing at 20 minutes total exposure—5 minutes front and back, and to each side—and working up generally to a total exposure of one hour. If a mercury vapour lamp is used, more intense radiations are obtained, and exposure starts at 4 minutes (one minute in each position), working up to a total exposure of 20 minutes.

Ultra-violet radiations do not produce specific effects, but provide a valuable adjuvant method of treatment, resulting in a general feeling of well-being, in the activation of Vitamin D in the pigment cells of the skin, and possibly in raising the resistance of the body by increasing the bactericidal power of the blood against the generalized tuberculous infection.

Local actinotherapy is used in the treatment of tuberculous sinuses, when the discharge from the sinus at first increases and becomes more fluid, and later diminishes appreciably.

Balneotherapy.—Among natural aids to healing, suitably managed sea-bathing takes a high place. It intensifies and supplements heliotherapy and aerotherapy with which, in the open sea and on a sunny coast, it is naturally associated. Properly timed sea-bathing, followed by brisk towelling, a hot drink to stimulate reaction, and a short sun-bath, induces in selected patients a sense of exhilaration and well-being which nothing else can effect. Moreover, the value of heliotherapy is generally enhanced by the sea, which reflects the ultra-violet and luminous rays, but absorbs the red and infra-red rays. Complete immersion in the sea, or paddling or even spraying, is associated with deep gasping respiration which expands the lungs, improves oxygenation of tissues, assists in the elimination of waste products, promotes

diuresis, and thereby results in a rapid increase of metabolism. Initial chilling, associated with contraction of the superficial blood vessels, must be followed by a brisk and healthy reaction, when the vessels become dilated, the tissues become flushed with blood, tissue oxygenation is increased, and the beneficial effects are induced in both healthy and diseased tissues. This stimulating treatment is invaluable in those who respond satisfactorily, but the patients must be carefully chosen, as otherwise more harm than good may result. Young children under the age of five, weakly and debilitated patients, and those with cardiac or renal complications or pulmonary disease must be excluded. Sea-bathing should be considered for those patients suffering from quiescent non-respiratory tuberculous lesions, or for those who do not respond satisfactorily to other therapeutic measures, and in such carefully selected cases it is an invaluable adjuvant method of treatment. Those suffering from discharging tuberculous sinuses respond so well to the drugs now available, and to dressings carried out with a strict aseptic technique, that exposure to the sun and sea-bathing is no longer indicated.

LOCAL ORTHOPÆDIC TREATMENT

The principles of local treatment are:—

(1) Recumbency and removal of weight-bearing.
(2) Immobilization or mechanical treatment.
(3) Prevention and correction of deformities.
(4) Rehabilitation and restoration of function.
(5) After-care and follow-up for many years.

(1) Recumbency and removal of weight-bearing.—In the initial and active stages of non-respiratory blood-borne tuberculous lesions, rest and recumbency are essential because the patient is suffering from a tuberculous bacillæmia This principle must be carried to its logical conclusion, even when the local lesion, for instance a tuberculous dactylitis, does not of itself apparently merit such irksome treatment of a general nature in an open air hospital. When the available evidence suggests that the disease is under control, the patient looks and feels well, there is no pyrexia, appetite is good, there is a gain in weight, the blood sedimentation rate has dropped to normal limits, and there is no secondary anæmia, patients with lesions of the upper limb may become ambulant, provided local treatment in plaster, splints or other appliances is continued. Removal of weight-bearing in children necessitates the use of some form of restraint to ensure that they remain recumbent.

(2) Immobilization or mechanical treatment.—Immobilization of the spine or affected joint is secured by plaster of Paris, or by a variety of splints and appliances, which are considered under the various specific lesions. Ultimately when the disease is quiescent and the patient becomes ambulant, continued immobilization in a celluloid,

leather or other type of splint is essential until the disease is arrested, unless bony fixation by operation has been obtained.

The general principles relating to the use of plaster of Paris and celluloid splints are of such wide application that they will be considered separately at the end of this section

(3) Prevention and correction of deformities.—Deformities associated with prolonged recumbency and inadequate attention to the details of treatment must be prevented both at the site of disease and in other parts of the body. In the treatment of tuberculosis of the hip or spine, it is essential to prevent back knee or genu recurvatum, foot drop, talipes calcaneus with dropping of the forefoot, and external rotation deformities of the lower limb. The knee must be nursed in the slightly flexed position (3°–5°), using a knee pad, small sand-bag, or splint, and the foot supported at right angles to the leg, or in slight equinus, by a foot piece or shoe to which is attached an anti-rotation bar. Correction of deformity at the site of disease in tuberculous disease of the spine, hip or knee, is considered with the treatment of the individual lesion.

(4) Rehabilitation and restoration of function.—Prolonged recumbency and immobilization is associated with widespread muscle weakness and wasting, with laxity of ligaments, and with impaired function of the locomotor system as a whole. Throughout the course of treatment this must be borne in mind, and the movements and activities of those parts of the body not immobilized must be encouraged (Fig. 1). Carefully controlled physiotherapy and exercises are necessary when the disease becomes quiescent, for example back raising exercises (but no flexion or lateral movements) in the ventral position, following immobilization for tuberculous disease of the spine. Walking exercises are essential when the patient first becomes ambulant, but no attempt must be made at forced mobilization of tuberculous joints.

(5) After-care.—Prolonged after-care and follow-up is essential after a patient with quiescent disease is discharged from hospital, and this can best be done at widely dispersed orthopædic clinics, so relieving the patient of the necessity of making a long journey to the parent orthopædic hospital. Clinical and radiological progress is observed, splints and appliances are renewed or repaired, and in due course gradually discarded, and the patient is kept under observation (maybe for five years or more) until the disease can be regarded as arrested.

Plaster of Paris.—Plaster of Paris may be used (1) to provide the most efficient means of immobilization in the form of splints or jackets, (2) for plaster beds and turning cases, (3) to provide a positive cast on which celluloid, moulded leather, and other splints can be made Immobilization by extensive plaster splints is not recommended in the early stages of treatment for lesions of the spine, hip and knee, as general treatment on the lines already laid down cannot then be carried out. Plaster of Paris affords a ready means for the surgeon to be his

own efficient splintmaker, but to be really satisfactory, skill in its application must be acquired, and suitable plaster bandages used. These must be neatly applied, properly reinforced to combine strength with lightness, and adequately moulded. Moulding should be carried out over the soft tissues adjacent to prominent bones, for example immediately below the clavicle, above the iliac crests, proximal to the femoral condyles, in the sole of the foot between the heel and the anterior arch, and on the plantar aspect of the toes. Plaster splints must be extensive enough to be adequate and efficient, and in the case of the knee joint must include the hip, ankle and foot. If the hip is excluded, and the patient is allowed to sit up with his knee extended in plaster, undesirable stretching of the hamstrings will occur. Inclusion of the foot will prevent foot drop.

Plaster of Paris is especially valuable after the disease has become quiescent, when healing and consolidation are commencing, and when further immobilization is necessary. During the early active stages of disease, other methods of fixation are to be preferred.

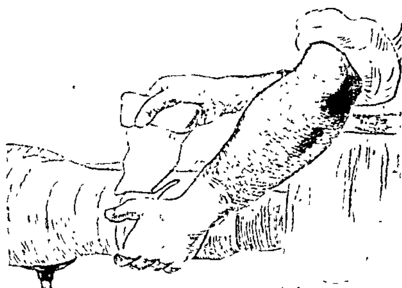


Fig. 2.—Application of plaster of Paris in tuberculous hip joint.
Note method of pleating bandage

The plaster bandage.—Ordinary book muslin, consisting of about 32 strands to the inch, should be torn in strips of suitable width and six yards in length, and the edges frayed of two or three strands to avoid the annoyance of strips of cotton catching the fingers during the application. The bandage should be loosely but snugly rolled in a large shallow bowl containing recently warmed, superfine plaster of Paris, in such a way that enough plaster is incorporated.

For a splint the bandage should be soaked in lukewarm water; for a cast, warm water is better as the set is more rapid.

Closely fitting vesting or stockinette should be applied to the trunk or limb to be plastered, for skin tight plasters are not recommended for

tuberculous lesions, whatever may be their merit in the treatment of fractures. The plaster bandage is put gently sideways into a full bowl of water to ensure rapid and thorough contact of water and plaster. When the bubbles of air have ceased to rise to the surface, each end of the bandage is grasped and squeezed tightly as it is lifted out, to get rid of the surplus water without disturbing the plaster.

The bandage should be wound loosely round a limb or trunk to avoid constriction, a pleat should be made wherever the direction of application is altered, and no reverse turns are permitted (Fig. 2). All bony points should be carefully protected in thin subjects with pieces of felt, and ample windows should be cut out in a jacket over the ventral surface of the body to allow room for respiration and digestion, and in the region of affected joints to permit observation. The edges of the plaster should be trimmed, the subjacent vest turned over the plaster edge and stuck down by plaster cream (5 parts plaster, 3 parts water). In order to limit the weight of the splint, plaster slabs or strips should be incorporated and used for reinforcement. Strips of metal, wood, etc. should not be used as they tend to work loose When dry, plaster cream should be applied to produce a polished surface and lengthen the life of the splint. Care should be taken to prevent the formation of sores under the plaster, by preparing the skin before application, and by avoiding undue pressure on any surface with bone immediately subjacent. If a patient complains of severe constant burning or boring pain over a bony point, a window should be cut out to relieve pressure If this is not done, the pain will pass off, as the area becomes anæsthetic, and a pressure sore will develop This will become obvious in due course by the presence of an unpleasant smell, or by soiling of the plaster.

A good plaster splint should be light, strong, and well moulded.

Celluloid splints.—In the later quiescent stages of disease, when weight bearing is resumed, but immobilization is still essential, celluloid splints are invaluable, especially for children. They are light, clean and hygienic, and are made to fit perfectly, so providing admirable support and protection. They can be made for lesions of the upper limb, for spinal caries, and for tuberculosis of the hip and knee Plaster bandages are applied to the part of the body to be splinted, and the splint is cut off immediately before the plaster has set firmly. The negative plaster shell is closed at one end by plaster bandages and filled with plaster cream When this has set the negative shell is removed, the positive plaster cast is moulded carefully, and a smooth surface is obtained by the application of a thin layer of plaster cream. Non-inflammable celluloid solution, made by dissolving celluloid in acetone and adding an appropriate quantity of calcium chloride, is then painted on successive layers of butter muslin cut to fit the cast accurately. Twelve to twenty layers of muslin may be required to provide a splint of suitable thickness and strength The splint is removed from the cast, fitted on the patient, and trimmed by cutting

away the redundant parts. Eyelets are inserted for lacing, the edges are bound with leather, holes are punched for ventilation, leather straps and buckles are applied if necessary, and the splint is reinforced and strengthened by duralumin strips.

Block leather splints are also moulded on positive plaster casts, but in the future splints made from suitable plastic materials may be more widely used.

SURGICAL TREATMENT

The principles of surgery form the basis of conservative treatment for non-respiratory tuberculosis, and during recent years the indications for operative intervention have become more clearly defined. There has emerged on the one hand a more general acceptance of the necessity for initial conservative treatment, and on the other a keener appreciation of the value of certain operative procedures, complementary to the former, designed to achieve more stable and satisfactory end results. It has already been established that many of the potential dangers and complications formerly associated with direct operative interference have been largely eliminated since the advent of streptomycin and P.A.S.

Although this is not the place for a detailed description of certain major operative procedures, some of the indications for operative intervention may properly be considered.

Lymph gland and joint biopsy.—When tuberculosis of the knee is suspected, confirmation may be obtained by inguinal gland biopsy, provided the appropriate lymph gland is removed, or by opening the knee joint, and after inspection removing a small portion of synovial membrane for examination. Joint biopsy is desirable when systemic streptomycin is to be used, if the diagnosis has not been confirmed by other means.

Extra articular arthrodesis.—Ilio-femoral or ischio-femoral arthrodesis is the treatment of choice when an unstable fibrous ankylosis of a hip with increasing adduction deformity is present. The latter procedure, using a stout tibial graft as described by Brittain* or Foley,† has the advantage that both the osteotomy to correct deformity and the arthrodesis are performed at the same time. It is carried out in the quiescent stage, usually in adolescence or later.

In spinal caries, bone grafting by a modified Albee or other procedure, to secure fusion of the affected and adjacent areas of the spine, is an invaluable operation when marked instability is present. The disease should be consolidated and quiescent, and the result will remain satisfactory, unless recrudescence of the tuberculous process occurs.

Relief of paraplegia in spinal caries.—Paraplegia is treated by conservative and mechanical measures in the first instance, when hyperextension at the site of disease, and head traction and pelvic

* Brittain, H. A. (1952), "Architectural Principles in Arthrodesis." Livingstone.
† Foley, W. B. (1949), *J. Bone Jt Surg.*, xxxiB, 222.

countertraction are used. If the condition is caused by a paravertebral abscess increasing in size and tension, costotransversectomy should be performed. In other cases where the paraplegia does not improve with conservative measures, antero-lateral decompression of the cord may be carried out. Laminectomy is performed far less often than in the past, but it may prove a useful procedure in intractable paraplegia, when decompression of the cord provides the only hope of obtaining improvement.

Extirpation of local disease.—This procedure may be adopted in certain cases in order to shorten the duration of disease, or to remove a potential focus of danger and thereby reduce the risk of dissemination. The removal of quiescent tuberculous cervical lymph nodes, of the astragalus when it is the main focus in tuberculosis of the ankle or tarsus, and excision of the knee to secure arthrodesis, are good examples of such measures.

Tuberculous abscesses of bony origin.—A detailed description of *the methods of treatment is given here as it does not appear elsewhere* in this book. It will be appreciated that a tuberculous or cold abscess is not an abscess in the true sense of the word, for it does not contain pus cells and polymorphonuclear leucocytes, but tuberculous debris and caseous degenerated material, largely the result of an impoverished blood supply associated with tuberculous endarteritis However, with this reservation, and for the purposes of easy description, the phrase tuberculous abscess is retained. An active and extensive bone lesion is usually, but not necessarily associated with an abscess, a large abscess rapidly refilling after repeated aspirations may be found with a minimal bone lesion; and conversely, gross disease may be present when no abscess can be detected Whenever it becomes necessary an abscess should be evacuated by aspiration repeated as infrequently as possible. The indications for aspiration are an accessible abscess (1) increasing in size, (2) tracking away from the causative lesion, (3) passing through the deep fascia and therefore likely to involve the overlying skin. Aspiration is not necessary for a small deep abscess stationary in size, or becoming smaller, because such a collection will either absorb or calcify

A modified Record (Gauvain) syringe of 10–20 c.c. capacity is employed, fitted with a trocar and cannula, and a blunt pointed probe. The calibre of the cannula should be 1·5–2 mm In young or nervous patients a short intravenous or inhalation anæsthetic is desirable, but in the majority of subjects a local anæsthetic, raising an intradermal wheal, is recommended Freezing of the skin does not facilitate the subsequent aspiration and is not recommended. When the site of aspiration has been selected, and the patient has been suitably anæsthetized, the skin should be punctured with a tenotome, and then thoroughly cleansed with Cetavlon, so that the trocar and cannula can be passed directly into the subcutaneous tissue, and the danger of introducing skin organisms and secondary infection thereby minimized.

The cannula should never be introduced directly over the abscess because of the danger of subsequent sinus formation, but should enter obliquely so that when it is withdrawn a well sealed track and valvular closure is effected. Thus when aspirating a psoas abscess the skin to the lateral side and below the anterior superior iliac spine should be well drawn over towards the umbilicus, and the cannula then introduced immediately proximal and to the inner side of the iliac spine. When the aspiration has been completed, and the cannula withdrawn, the site of entry through the skin will be found about 1 in. lateral to and below the prominent iliac spine. The limits of the abscess are defined by the left hand, the fingers pushing aside and guarding the peritoneum and viscera, whilst the thumb steadies the hand by pressing on the ilium (Fig. 3). The cannula loaded with the trocar is directed backwards, skirting the deep surface of the ilium, and by a gradual deliberate movement the abscess is entered. Immediately there is a characteristic sensation of freedom and lack of resistance. Having entered well into the abscess cavity, the trocar is withdrawn, leaving the cannula *in situ*. Pus sometimes wells up and drains from the cannula into a kidney dish, but usually it is necessary to attach the syringe and aspirate until no more pus can be withdrawn. The probe is then inserted to clear the cannula of caseous debris, when further pus may be aspirated. The probe is again inserted, and the cavity explored by elevating or depressing the cannula and aspirating in different positions. When the evacuated pus becomes tinged with fresh blood, no further attempt to empty the abscess is made, until aspiration is again deemed to be necessary. At this stage the cannula, loaded with the probe to prevent the deposition of any caseous material in the track of the needle, is gently withdrawn, and the opening sealed with a small gauze patch soaked in collodion or mastisol.

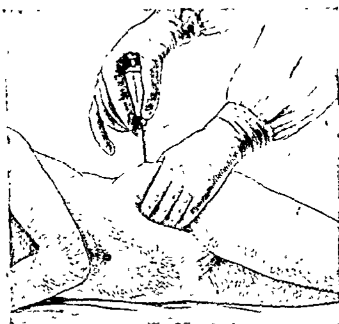


Fig. 3.—Aspiration of psoas abscess.

The principles adopted in aspirating a psoas abscess apply to abscesses elsewhere. An abscess should never be aspirated directly over the swelling, but always at some distance away, through healthy tissue, so that the track is self-sealing or valvular. Tissues which may be invaded by the abscess if it refills and extends must be avoided.

Abscesses in connection with the hip joint tend to track down the limb (and may be found in the region of the knee), and therefore the site chosen for aspiration must be proximal and to the lateral side of the abscess.

Aspiration may be required several times, and usually the abscess tends to diminish in size, and less pus, thicker in consistency, is withdrawn at successive aspirations. As the abscess diminishes in size its walls become denser and more sclerosed, and eventually a diminishing fibrous mass replaces the old abscess cavity, and seals off effectively its causal lesion towards which it shrinks and eventually disappears.

The practice of using modifying oily or etheric fluids in an attempt to liquefy caseous material has now almost been abandoned, as the resulting inflammatory reaction did not always produce a satisfactory result. However, pus withdrawn at aspiration may be replaced by streptomycin or para-amino salicylic acid apparently with gratifying results, as yet too early to assess

When the skin overlying a tuberculous abscess becomes involved at one point, aspiration will not usually prevent further undermining, wider involvement, and sinus formation. It is advisable in such circumstances to make an incision ½ in. in length through the involved skin, or if it is thin and bluish in colour to excise it by a small elliptical incision The abscess can then be emptied by manual expression, and the fluid contents and masses of caseous material evacuated, until tingeing with fresh blood becomes apparent. One gramme of streptomycin is inserted locally, and the wound closed with one or two mattress skin sutures only. If the abscess refills it can be readily emptied by aspiration repeated as necessary The same procedure should be carried out in those cases in which aspiration cannot be successfully performed because caseous material blocks the lumen of the cannula, and is preferable to the use of modifying fluids

Tuberculous sinuses.—When a sinus develops, following an abscess associated with an osseous or articular lesion, it is imperative to prevent secondary pyogenic infection A dressing is applied consisting of a small pad of gauze about 2 in square, covered by a slightly larger pad of white absorbent wool, and then by a large layer of unbleached non-absorbent wool, and bandaged carefully with a calico bandage. Such a procedure, carried out as infrequently as possible, with full aseptic precautions—the dresser wearing a mask, and using a no-touch technique—has proved invaluable in dressing sinuses in the region of the hip joint in young children, when soiling from the excreta cannot otherwise be avoided. Even in the absence of secondary infection a tuberculous sinus may take weeks or months to heal soundly. Formerly the outlook for the patient with a tuberculous sinus or multiple sinuses was not good, because secondary infection often supervened with the ultimate development of lardaceous disease Local instillations of streptomycin (one gramme daily), combined with systemic P A.S. to prevent resistant strains emerging, or local P.A S alone, will often

ensure healing of sinuses of long duration within a few weeks. If the organism causing secondary infection is insensitive to penicillin and streptomycin, the appropriate alternative antibiotic should be substituted. Although the effect of streptomycin and the other drugs enumerated, on tuberculous bone and joint lesions remains to be demonstrated, there is no doubt as to their value in securing healing of tuberculous sinuses. The passage of time will show whether these gratifying early results are permanent. These measures for dealing with sinuses must always be combined with the appropriate orthopædic treatment of the underlying bone or joint lesion. Curettage of bone debris, or of the sinus track, may sometimes be advisable.

ORTHOPÆDIC TREATMENT OF INDIVIDUAL LESIONS

Although the principles of the local treatment of various lesions are generally accepted, many different methods and forms of apparatus are used to attain the objects desired, and in spite of this divergence the results obtained are more or less satisfactory in the hands of those experienced in the use of any particular method. A brief outline only of some of the methods used can be given.

Spine.—In early active disease recumbency and immobilization with the back firmly supported, is combined with hyperextension at the site of disease in order to diminish the pressure between the affected vertebræ aggravated by muscle spasm. Hyperextension is comparable to traction applied in disease of the hip joint, and should be used for a period of 6–12 months, until there is clinical and radiological evidence that the disease has become quiescent. Hyperextension at the site of disease is obtained by placing a wedge pillow or wooden block under the mattress of a Berck or Gauvain box, by bending a Bradford frame, or on a plaster bed by removing felt pads surrounding the kyphos.

In upper dorsal and cervical disease the shoulders must be well supported and raised on blocks, and the head allowed to drop back fully so that the anterior common ligament becomes taut, and an effective factor in immobilization.

In growing children when the disease has ceased to be active and progressive, compensatory curves must be developed by transferring pressure from under the site of disease, and applying it 2 in. to 3 in. away to the adjacent spine. The diseased part of the spine is thereby consolidated, whilst the compensating curves developed ensure a good upright posture of the spine as a whole when the child becomes ambulant. This phase of treatment must be continued for a year or longer, and until the diseased part of the spine becomes well calcified.

As a result of this method of treatment the erector spinæ muscles become very weak and wasted, and therefore before the patient becomes ambulant, he should be nursed in the ventral position for several hours each day for a period of two or three months, and back raising resisted exercises carried out.

A well moulded plaster jacket should be applied when the patient

becomes ambulant (Fig. 4), and this should be replaced after two or three months by a celluloid jacket or spinal brace. It may be necessary for this support to be worn for eighteen months to three years, or more, depending on the progress of the individual patient, and it is gradually discarded when clinically and radiologically the disease is arrested, and no further change is observed. In upper dorsal and cervical caries, the support must extend up to the chin and include the head, but in lumbar caries a spica jacket or support including one thigh is not now regarded as desirable.

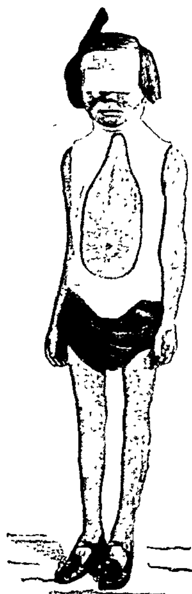


Fig. 4.—Minerva plaster of Paris jacket in cervical caries.

Compensatory curves cannot readily and satisfactorily be obtained in adults and adolescents, when growth has practically ceased, and if consolidation is inadequate and the spine unstable, the question of spinal fusion in the quiescent stage must be considered Spinal fusion is unnecessary when satisfactory consolidation and calcification has occurred

In upper dorsal and cervical caries, and in the conservative treatment of paraplegia, head traction in the longitudinal direction is desirable, in addition to hyperextension at the site of disease. This must be accompanied by pelvic counter traction, or by appropriate tilting of the patient. As traction may be necessary for several months, skeletal traction is inadvisable, a halter under the chin is painful, and interferes with the development of the lower jaw, and webbing applied to the head in the usual circumferential way slips off repeatedly. The following method, using a mitred head-piece, is invaluable.

Head or cervical traction.—A length of webbing 1 in. wide, sufficient to encircle the head and buckle in front, is mitred above the ear on each side, so that the anterior part passes horizontally forward to the forehead, and the posterior obliquely downwards and backwards to pass below the external occipital protuberance This head-piece may be lined with chamois leather, or felt pads may be placed below the occipital protuberance, and between the forehead and the webbing. Traction is applied through webbing sewn to the apex of the mitre above each ear, and as it is increased the head-piece does not pull off, but grips the head more firmly (Fig. 5).

Plaster bed.—This is made by applying plaster of Paris bandages or muslin sheets wrung out in plaster cream to the patient, suitably supported in the ventral position, and should extend up to include the head, and down to support the thighs. It is rendered smooth on its deep surface by applying plaster cream; when thoroughly dry it is lined with vesting, and then raised and supported on a wooden or metal frame to facilitate nursing attention. It is used in conjunction with a ventral plaster turning case. The plaster bed fits the contours of the back accurately, and is particularly useful after an operation for spinal fusion when rigid immobilization is essential. In the conservative treatment of paraplegia, or when hyperextension or the development of compensatory curves is desired, other methods are more satisfactory.



Fig. 5.—Mitred head traction.

Berck spinal board.—This method, popularized by Gauvain in this country, consists of a firm hair mattress lying in a flat wooden tray, with the base perforated by a number of holes for purposes of ventilation. The patient is immobilized by means of a jean jacket buckled round the trunk and attached by its four corners in a cruciform manner to the side pieces of the board. By the insertion transversely of a wooden block of appropriate height under the mattress, hyperextension or the development of a compensatory curve may be obtained. Immobilization may be maintained when nursing attention is given, if a part of the wooden side piece of the board is hinged and lowered, and a

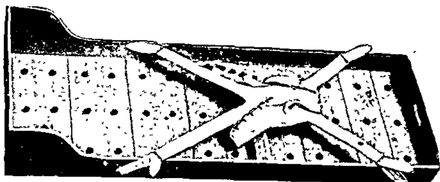


Fig. 6.—Spinal board and jacket for spinal caries.

rectangular metal receptacle is introduced after removal of a small sectional part of the mattress. The patient's back is inspected by grasping the shoulders with one hand, and the pelvis on the same side with the other, and rolling the patient over to the opposite side. As this is done, the patient must hold the extended arms stiffly to the sides of his body. In cervical caries the head and neck fully hyperextended can be immobilized effectively by means of a suitable splint (Fig. 7).



Fig. 7.—Cervical immobilization in hyperextension with traction.

Bradford frame.—This type of gas piping frame, popular in America, was modified by Pugh of Carshalton to provide a very efficient spinal frame and carriage (Fig. 8). Nursing attention is

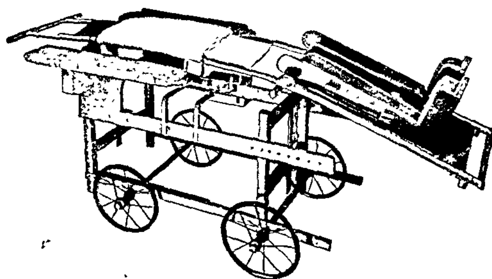


Fig. 8.—Pugh spinal frame and carriage.

readily carried out without interfering with the efficient immobilization; hyperextension and the development of compensatory curves are obtained by bending the frame at the appropriate levels, and the patient can be transported from place to place in comfort, and without detriment to the spine. The feet are supported by a foot board, and the legs are exercised by lowering a flap (Fig. 1). This apparatus is suitable, with few exceptions, for all patients with spinal caries, until ready to be turned into the ventral position, and for the conservative treatment of paraplegia.

Paraplegia.—Seddon and Butler* have done a great deal to clarify our views on the etiology and treatment of Pott's paraplegia. It has already been stressed, and it is reiterated here, that in all types initial conservative treatment by adequate hyperextension, head traction and pelvic counter traction is advisable, together with the treatment of urinary or double incontinence, if present, and careful and skilled nursing attention to the skin and pressure points. Satisfactory recovery frequently follows.

Conservative treatment is also indicated when the paraplegia is of sudden onset, and the result of a vascular lesion, or when it is associated with an active tuberculous lesion, or of reactivation at the site of disease.

When X-ray examination made about six weeks after the onset of paraplegia reveals that it is associated with a paravertebral abscess increasing in size and tension, and presumably exerting greater pressure on the spinal cord, costo-transversectomy is indicated. Relief is sometimes dramatic and the paraplegia improves rapidly in the course of a few days.

Mechanical pressure on the cord, sometimes revealed only by tomography, and due to a sequestrum, or to subluxation at the site of disease, may be relieved by antero-lateral decompression of the cord. When the prognosis is apparently hopeless after months of efficient conservative treatment, and there is no indication for the above operative procedures, laminectomy is justifiable. These operative procedures are described in detail elsewhere in this book.

Hip joint.—During the active progressive stages of the disease the patient must be treated in recumbency with traction applied to the immobilized affected hip. Traction is usually necessary for six to twelve months, and is discontinued when the disease ceases to be active, when muscle spasm can no longer be elicited, and when X-ray examination reveals no further spread of disease, and the commencement of marginal recalcification. Slight residual muscle spasm may be demonstrated by Gauvain's test, which is performed by placing one hand on the lower abdominal quadrant and rotating the affected limb to its limit of internal or external rotation. When further slight, but forced, rotation is attempted, residual spasm will be felt in the lower

* Butler, R. W., and Seddon, H. J. (1935), *Brit. J. Surg.*, xxii, 738.

abdominal muscles. After cessation of traction, continued immobilization may be necessary for a year or more until clinically the hip is quiescent and there is radiological evidence of satisfactory consolidation and calcification.

The patient then becomes ambulant in a well-moulded plaster spica, so that with the hip immobilized, weight bearing is permitted. After

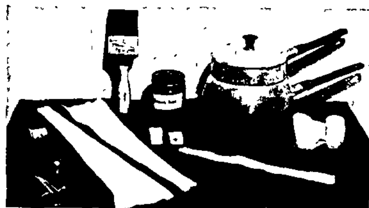


Fig. 9.—A, tray prepared for application of Böhler's paste extension.



B, Bohler's paste extension. First layer of stockinette applied.



C, Bohler's paste extension. Application completed.

about three months the plaster is replaced by a suitable splint, such as a celluloid hip spica, which is gradually discarded after a variable period of a year or two when the disease appears to be arrested. The optimum position for fixation is 10°–20° of fixed flexion, mid rotation and 5°–10° of abduction.

Conservative treatment usually results in an unstable fibrous ankylosis of the joint, which tends to adduct with the passage of time. For this reason an extra-articular arthrodesis is commonly performed

provides an easy and simple method of treatment except in the more acute forms of tuberculous disease of the hip, when immobilization is not adequate because of the movement and strain on the affected hip that occurs when nursing attention is given.

Fixed traction.—The affected limb is tethered to the raised end of the bed or special inclined frame, and as traction on the affected hip is considerable, it affords a ready and satisfactory method of treatment during the first few weeks, when marked muscle spasm is present. The patient is kept recumbent by adequate restrainers, but nursing attention is difficult, and this method should therefore be regarded simply as a temporary measure.

Sliding traction.—In the Pugh-Carshalton hip frame and carriage (Fig. 10), the patient is nursed on a horizontal frame which rests by

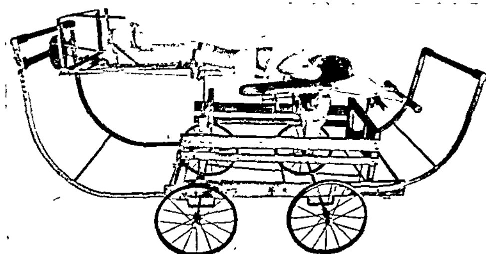


Fig. 10.—Pugh hip frame and carriage.

means of ball-bearing roller-skate wheels on an outer carriage, to which the affected hip is tethered by a suitable extension. Nursing attention can be given without disturbing the affected hip, and immobilization and traction is adequate and satisfactory. Traction can be varied by increasing or diminishing the slope of the metal trough on which the wheels rest, and should be such as to overcome the muscle spasm present.

Robert Jones abduction frame.—Both limbs are immobilized with the affected hip in the position of moderate abduction, whilst the pelvis is kept horizontal and at right angles to the long axis of the trunk. Immobilization is satisfactory, the fixed traction is reasonably adequate, and nursing attention can be given without disturbing the affected hip Excessive abduction of the hip, and strain on the epiphyses and ligaments in the region of the knee, associated with premature fusion of the distal femoral epiphysis must be avoided. This is probably the method most widely used in this country.

avoided, and careful weekly blood and urine examinations must be carried out.

When after about two months' treatment the patient's general condition shows signs of improvement, and there is evidence of retrogression in the nodes, septic foci, such as infected tonsils or carious teeth, should be eradicated. If this is done in the early stages, a brisk reaction may occur in the affected nodes with resulting enlargement and softening. Treatment on conservative lines is continued so long as the nodes become progressively smaller, more discrete, and firmer. If an abscess forms repeated aspiration may be necessary, but when a collar stud abscess with early skin involvement is present, a small incision should be made, the contents of the abscess expressed, and the wound sutured. Excision of undermined unhealthy skin should be carried out, and the resulting tuberculous ulcer treated by local actinotherapy, streptomycin and P.A.S. When, after treatment for four to six months, no further change is observed, local complete excision is desirable if a residual mass of nodes remains. The results of late excision, following prolonged conservative treatment, are excellent, whereas early excision is often followed by recurrence in residual seedlings. Treatment in the early stages by radium or X-rays is not recommended, as the resulting fibrosis renders subsequent excision more difficult.

With widespread blood-borne involvement of the cervical lymph nodes, systemic treatment by streptomycin or P.A.S. is recommended.

ABDOMINAL TUBERCULOSIS

When tuberculous sputum from a pulmonary lesion, or milk containing the bovine type of tubercle bacillus is swallowed, the mesenteric lymph nodes or peritoneum may become involved, following entry and absorption through the lower ileum. Tuberculous mesenteric adenitis frequently simulates appendicitis, and is often diagnosed following laparotomy for appendicectomy, or when calcified nodes are seen on X-ray examination. Tuberculous peritonitis may be of the ascitic, caseous or adhesive type. In the ascitic form the peritoneum is studded with macroscopic tubercles, and the abdomen may be grossly distended owing to the presence of free fluid Marked improvement may follow laparotomy and the removal of as much fluid as possible. In the caseous form the abdomen is enlarged, and tuberculous masses including thickened omentum may be palpable In the adhesive type, widespread intraperitoneal adhesions, with loculated collections of fluid, are present, the abdomen is frequently scaphoid, and recurrent attacks of subacute intestinal obstruction may occur. The prognosis in this type is not usually good, particularly when fistulæ are present

The patient with tuberculous peritonitis or mesenteric adenitis requires prolonged general treatment, on the lines already laid down, in an open air hospital, and a light, nourishing fibre-free diet should be

prescribed so as to limit peristaltic movements so far as possible. General actinotherapy may be of value in certain cases, and antispasmodics are useful in relieving the colic of partial intestinal obstruction. Laparotomy may be necessary as a diagnostic measure, or for intestinal obstruction. The indications for the administration of antibiotics have not yet been clarified.

GENITO-URINARY TUBERCULOSIS

This is referred to in Chapters XL and XLIV, Vol. II.

CHAPTER II

GENERAL ORTHOPÆDICS

By H. JACKSON BURROWS

INTRODUCTION

APART from prevention, the chief object of orthopædic surgery is the restoration of function in a member that is disabled by maldevelopment, injury or disease. Improvement in shape or appearance may be desirable for æsthetic reasons, but always the effect of treatment upon physical function should be studied. Moreover, the future as well as the immediate result must be borne in mind For example, operative or manipulative procedures upon a joint may cause improved function for a few years, but experience may show that they are unjustifiable because they lead later to the degenerative changes of osteoarthritis. Arthrodesis and tendon-fixation carried out upon young children improve function but may interfere with growth, or growth may lead to an alteration of strains, either of which tends to produce a fresh deformity.

In a deformity there may be a contracture of skin, muscle, tendon or ligament, holding one or more joints in a fixed position or restricting their full range of movement, a joint may be dislocated or a bone malformed or crooked, or there may be an actual loss of part of a limb in consequence of congenital maldevelopment or of injury or disease. But in other cases the condition that requires treatment is a loss of function rather than of form. Such are many paralytic conditions (anterior poliomyelitis, spastic paralysis and motor peripheral nerve injury) and injuries of muscles, tendons and ligaments.

In the first of these groups the correction of shape must be subordinated to the improvement or maintenance of function. The simplest and most direct surgical method may not be the best. For example, in congenital club foot, the shape of the foot can be corrected by a gross surgical operation, the removal of a part of the tarsal bones, but this interferes with the action of all the tarsal joints and leaves a foot that looks a good shape but is really only about as useful for walking purposes as a stump. Scarring of the skin often interferes with mobility or even causes deformity. If this possibility is foreseen much may be done to prevent it The part may be splinted during healing to prevent contracture, the skin around may be kept supple by massage, and in suitable cases a granulating area may be excised, the skin undercut and mobilized, and a secondary suture carried out. In

skin grafting, the effect upon function should be remembered. Areas covered by Thiersch or Wolff grafts usually show adherent scars. If the graft has to cover exposed tendons these grafts will not give satisfactory results and a pedicle graft will be required. The same may be true when muscle is exposed or when the scar is left adherent to the capsule of a joint.

Deformities in which muscles or tendons are shortened are not necessarily to be treated by division or lengthening of the tendon. This procedure inevitably weakens the muscle, and the consequent loss of power may be important. Efforts should be made to correct the shortening by exercises, serial splinting, manipulation under an anæsthetic or some form of traction. In some cases it may be wiser to leave the deformity. This is often the case when the tendo Achillis is a little short in a paralysed and weakened leg. When weight is placed on the foot the knee is forced into hyperextension, in which position it is stable even if the quadriceps is weak or absent. If the tendo Achillis is lengthened, the foot may dorsiflex beyond a right angle, and the stability of the knee is diminished.

Contracted ligaments may require division but it should be remembered that some ligaments are essential to the stability of the joint. They should, if possible, be stretched rather than cut.

If a bone is crooked from injury or disease it may perhaps be straightened by osteotomy. But it is not essential to carry out this operation at the site which appears anatomically to be correct. Whenever possible, the osteotomy should be performed at a level at which the bone is normal and not at the site of old disease or injury. Stiff joints can sometimes be mobilized by the operation of arthroplasty; but before this is undertaken the surgeon should decide whether the function required is better with a sound fixed joint than it would be with the rather imperfect and perhaps unstable joint that the operation offers.

When there is loss of function rather than deformity, all possible non-operative methods should be considered first. This is particularly the case in paralytic deformities, and the use of splints, appliances, exercises and re-education should be given a prolonged trial before such operations as arthrodesis and tendon transplantation or fixation are advised

In fact, in orthopædic treatment, operation is only one part of the work It should be used only after careful consideration and as part of a planned campaign in which the pre-operative and post-operative treatment is just as important as the operation itself.

SOME POINTS IN THE TECHNIQUE OF ORTHOPÆDIC OPERATIONS

General surgical principles apply to orthopædics as to any other branch of surgery, but reference to a few points here will save repetition later.

Instruments.—These should be of the best quality and as few as the work in hand allows. A small soft-tissue " foundation set " is supplemented for each operation as necessary; an indication of these additions is given with the various operation or groups of operations. A suitable foundation set comprises: Esmarch's bandages, pneumatic tourniquets, ligature and suture materials, including needles, towel

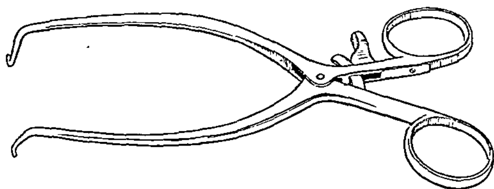


Fig. 11.—Self-retaining retractor suitable for orthopædic work.

clips, scalpels, dissecting forceps, scissors (e.g. straight Mayo's), retractors (two blunt hooks, two Langenbeck's with ample handles, self-retaining—Fig. 11), tissue forceps (gentle, such as Littlewood's or Allis's, not harsh like the ubiquitous Lane's), aneurysm needles, probe, plain artery forceps, two Köcher's forceps. These instruments should

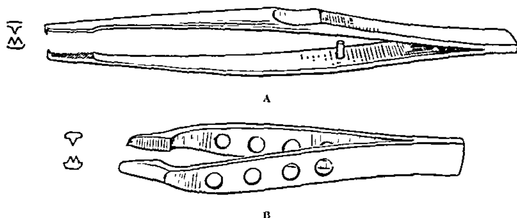


Fig 12.—Points of dissecting forceps with which sutures can be gripped in " no-touch technique."
A. Lane's B. Jeans's

be carefully selected " No-touch technique " demands needle holders of simple pattern (on the Spencer Wells principle and with box joints) and forceps with suture grips (Fig. 12); it is important to see that the grips meet squarely and continue to do so whatever pressure is applied —some gape distally as pressure is increased; there should be no asperities to fray or cut the sutures. For holding continuous sutures,

the forceps shown in Fig. 13 are much less tiring to the assistant than spring forceps. Bone instruments are described in Chapter V, p. 231, and plaster of Paris technique in Chapter I, p. 30.

Foresight is necessary in ensuring beforehand that every sort of retentive apparatus is ready. For instance, if a Thomas's knee splint is to be applied, not only should the correct size be ready in the theatre

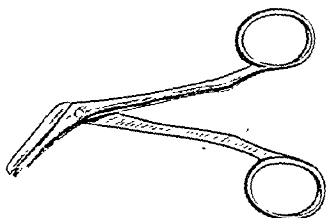


Fig. 13.—Forceps suitable for holding continuous sutures (Galabin's).

with fittings attached, but every detail of the bed suspension apparatus should be ready beforehand; if the operation is upon a hip, the patient may be brought to the theatre with traction straps already in place.

Preparation of the patient. General investigation and preparation.—The importance of knowing the patient's outlook and constitution, of caring for both, and of adapting the operation to them, is no less in orthopædics than in other branches of surgery, but needs no separate mention except to emphasize that the patient must be capable of collaboration

Posture and exercises —Nowadays that patients are often not allowed pillows behind their knees, for fear of thrombosis, a sagging mattress hyperextends the knees of a supine patient and is most uncomfortable for both knees and heels. Fracture boards are rarely needed if bedsteads are good and well maintained. If the patient is to be propped up the foot of the bed should be raised. If a particular position or fixation will be needed after operation, it is well—and sometimes essential—that the patient should be accustomed beforehand. For instance, if a plaster bed is necessary, the operation should be deferred until the patient is used to the bed and comfortable in it. Exercises which will be needed after operation should usually be taught beforehand, for instance quadriceps exercises before a meniscectomy or exercises for the intrinsic muscles of the feet before an operation for hallux valgus. Usually general exercises, including breathing exercises, are desirable, as well as local exercises.

Bowels.—No preparation of the bowels is essential for any orthopædic operation, and it is questionable whether it is even advisable. The most that can be recommended is the patient's customary aperient two days before operation and, in appropriate cases, a simple enema on the evening before operation.

Skin preparation.—Chemical sterilization requires full access of a suitable concentration of the antiseptic substance for a long enough time; these conditions have not been achieved in the skin. However, unless broken, it can usually be freed of all but its regular non-pathogenic residents by shaving if necessary, thorough washing with soap and water, and the use of fat solvents and the quicker-acting antiseptics like iodine in preference to the slow mercurial antiseptics. Because of their penetrating powers and because they rarely excite a skin reaction, kationic detergents, such as cetyltrimethylammonium bromide (cetrimide or Cetavlon), are often now preferred, but it should be borne in mind that they are neutralized by soap; for theatre use they need colouring, for instance with methylene blue.

The old practice of multiple skin preparations for several days before operation is to be condemned as not only unnecessary but harmful. It gave time for any slight abrasions, left by the initial shaving or the subsequent attentions, to become minor foci of infection by the time of operation. A single preliminary preparation and sterile towelling the night before operation suffices, a final painting being carried out on the operation table. The area prepared should always be liberal.

Operative technique. Position of the patient.—This should: (i) be safe, without risk of injury for example to the brachial plexus or to joints by stretching, (ii) be secure against accidental shifting, and allow counter pressure, by sandbags or otherwise, to such things as blows with mallet and osteotome, (iii) afford ample approach to the field of operation, including any secondary field that may be required, for instance for obtaining a graft from a distance, (iv) allow any necessary limb manœuvres, (v) allow convenient access and reasonable comfort to the assistants as well as the surgeon, (vi) avoid any unnecessary vascular congestion, (vii) allow the application of post-operative fixation with the least disturbance, (viii) allow radiographic control in appropriate cases, (ix) allow good illumination.

Towelling or draping.—In operating upon a limb it is almost invariably desirable or necessary to have it separately towelled so that it can be freely controlled and moved by a gloved assistant. In the process of towelling there are many opportunities of contaminating the outside of the towels and the gloves and gowns of the assistants; a meticulous drill by a well-trained team is imperative. The use of distinctively coloured sterile towels is a great safeguard against unnoticed gaps, and should by now be universal. No satisfactory way of shutting off the skin of the operation field itself has been devised. "Tetra" towels clipped to the skin edges are not always practicable, give a false sense of security and get in the way. Stockinette stuck on

with varnish is neater but even less efficient, leaving the cut skin edges bare, and distributing desquamated epidermis on remov[illegible] hasty use of diathermy has been know[illegible] rnish. For such [illegible] joint or expo[illegible]

Aseptic technique.—Because of a notion that the synovial membrane of a joint is more susceptible to infection than the peritoneum and that bone is more susceptible than the soft tissues, and because infection of joints or of bones may have such serious consequences, the importance of asepsis is much emphasized in orthopædic work. Great attention has been given to the no-touch technique advocated by Lane, in which no part of the wound—or anything that goes into it—is touched by the (gloved) hand. It is good that every surgeon who does meniscectomy should be able to do it by this refinement of technique, but it is bad that any surgeon should decline to put his finger into a wound, whether to gain information which might otherwise be missed* or in order to do well what cannot be done adequately with instruments. It is true that gloves do quite often become perforated, especially if they touch cut or broken bone, but it is important that a surgeon should keep a sense of proportion, so that devotion to the ritual of no-touch technique does not blind him to major errors of conduct; for instance, the true believer who expounds no-touch minutiæ through a mask that is pervious to the whole flora of his nasopharynx, strains at a gnat and swallows a camel. Besides good aseptic technique, which cannot be insisted upon too strongly, there are other factors in the avoidance of sepsis and these are too often overlooked—good general preparation of the patient, gentleness to the tissues, an adequate but not excessive exposure and good hæmostasis. The insufflation of large operation wounds with a penicillin powder before closure is permissible unless made an excuse for laxity during the intervention and provided the powder is without such harmful ingredients as the highly alkaline sulphathiazole.

Control of hæmorrhage.—Unless a tourniquet is appropriate, hæmorrhage is controlled as in general surgery. Even the bleeding from divided bone may be stopped by the everyday methods of pressure or the application of some other tissue such as muscle. Horsley's wax is occasionally useful for slight oozing, but should be used sparingly or an excess may escape later from the wound. Hæmorrhage which proves troublesome in the approach to a bone will often stop when levers have been inserted and separated enough to retract the soft tissues. In larger operations preliminary infiltration with *dilute* adrenaline solution† is invaluable; careful local control of hæmorrhage may be supplemented by blood transfusion during and after the operation, and the control of blood pressure with drugs by the

* "Put your finger in it or you'll put your foot in it," is often sound advice here, as elsewhere.

† Up to 100 *millilitres of 1 200,000* solution (or *250* millilitres of 1 500,000 solution), introduced through a valve-feed, spring return syringe

anæsthetist has a place not yet fully assessed. When possible, tourniquets are used. They cannot be applied ordinarily if the area of operation extends on to the most proximal part of the limb; and are inadvisable if they would interfere with structures involved in the operation—for instance, in suture of a fractured patella or olecranon, if the quadriceps or triceps is bound down by a tourniquet, approximation of the fragments is impeded Tourniquets should not as a rule be used in cases of peripheral vascular disease. The usual way of putting on a tourniquet before operation is to elevate the limb and apply firmly and evenly an Esmarch's bandage from hand or foot to the upper part, where it is fixed or a pneumatic tourniquet is applied immediately above it and as high as possible; the bandage is then unwound from the rest of the limb. For operations on the hands and feet, the tourniquet need be no higher than the widest part of calf or forearm, with special care that a calf bandage is not applied over the terminal part of the lateral popliteal (common peroneal) nerve. In minor operations with a local anæsthetic the contained adrenalin makes a tourniquet unnecessary. The great advantages of a pneumatic tourniquet are that a known pressure can be applied over a fairly wide area and that pressure can be released and restored without disturbance of the limb. This is specially important in the upper limb, where it is sometimes a practice to release the pressure temporarily at intervals of half an hour in a prolonged operation. Partial release of a tourniquet to a pressure between arterial and venous may lead to a big and even dangerous loss of blood in a short time. Consequently it is imperative to keep the apparatus in good condition, and to restrict its use to persons of proved competence, such as the anæsthetist or a trained theatre orderly. Otherwise the surgeon should apply the tourniquet himself, preferably before completing his own preparation for operation. If, alternatively, he decides to apply a sterile Esmarch's bandage after he is gowned and gloved and after the patient is draped, he should make sure that the bandage is cool. A recently boiled rubber bandage must be unrolled to cool it or it will burn the patient severely, theatre sisters seldom seem to know this danger. *The most important thing about putting on a tourniquet is to remember to take it off*, and everyone in the theatre as well as those who nurse the patient afterwards should feel a personal responsibility in the matter, though the prime responsibility is the surgeon's. A forgotten tourniquet threatens not only limb but life It is a good practice to tether the applied tourniquet to the operation table. There are two stages of an operation at which a tourniquet may be removed, either (*a*) before closure is begun, as in operations upon tendons of the hand and in major amputations, or (*b*) after the dressings and bandages have been applied. If a circular plaster is applied, it is better to have no other bandage between it and the cotton wool. On the other hand a circular plaster is sometimes applied when a plain bandage incorporating a plaster slab would suffice. The surgeon should satisfy himself that the circulation has been restored to the part before the patient leaves the theatre

Drainage of orthopædic operation wounds is hardly ever adopted. The chief safeguard against hæmatoma is careful hæmastasis supplemented by a snugly applied bandage or plaster over adequate cotton wool.

Plaster of Paris technique is described in Chapter I.

Post-operative care.—General post-operative care follows the usual principles. Local care—that is to say the care of any parts operated upon or involved in apparatus—assumes a special importance. After an operation upon a limb, *the first care must be for the circulation*: such implies constant vigilance; the limb is elevated (Fig. 14), it may



Fig. 14.—Relief of venous congestion and pain by elevation and cooling (Philoctetes bitten by a serpent, from the cover of Jacobson's edition of Hilton's *Rest and Pain**)

be cooled and, above all, any undue constriction is avoided or relieved—one cause of constriction is the forgotten tourniquet! If a plaster is split, care must be taken that no constriction remains, especially from a subjacent undivided bandage. Second to care of the circulation is the avoidance of localized skin pressure from plasters and apparatus, especially over bony points, for instance the pressure of plaster over the heel or traction ("extension") straps over the malleoli. Such skin pressure not only tortures the patient, but, unrelieved, causes necrosis of the compressed tissues. The pressure of tight strapping, a splint or plaster over a nerve, such as the lateral popliteal (common peroneal) at the neck of the fibula, may cause paralysis

* See Editor's Preface to the Fifth Edition, 1892, London, vii.

and sometimes sensory loss in its distribution; recovery is usual but not invariable. *Unexplained pain calls for unremitting search for a local cause*: neglect of this is responsible for much unnecessary suffering, and is all too common.

OPERATIONS FOR CONGENITAL DISLOCATION OF THE HIP

Operations in congenital dislocation may be classified as:

(1) Operation to amplify diagnosis—arthrography;
(2) Operations to produce reduction,
  (*a*) Closed (manipulative) reduction,
  (*b*) Open reduction;
(3) Operations to maintain reduction,
  (*a*) Acetabular shelf operation,
  (*b*) Rotation osteotomy to correct femoral anteversion;
(4) Operations in irreducible cases,
  (*a*) Osteotomy for stabilization,
  (*b*) Manipulation, osteotomy, arthrodesis, arthroplasty or nearthrosis for joint strain or arthritis,
  (*c*) Limb equalization.

Arthrography.—Sometimes reduction of a congenital dislocation of the hip in an otherwise suitable case is prevented by such anatomical obstruction as a tight or inturned labrum acetabulare (labrum glenoidale) or "limbus", an hour-glass constriction of the capsule, complete filling of the acetabulum, or an enlarged ligamentum teres. Such obstacles may be revealed by arthrography, which may therefore be carried out usefully when manual reduction fails. Indeed there is much to be said for making this a routine procedure in all cases, so that open operation can be carried out without previous attempts at conservative treatment in those cases in which it is doomed to failure for anatomical reasons. On the other hand, conservative measures sometimes succeed in the face of decidedly forbidding arthrograms, and the routine use of these would seem to encourage excessive resort to open operation.

Various contrast media, including air, have been used. Diodone, B.P.C. ("Per-abrodil" of Messrs. Bayer), is suitable, being a mobile and seemingly non-irritant liquid; it is obtainable in the appropriate strength of 35 per cent. in ampoules of 3 c.c. which is usually enough for one joint. The other requirements are a 5 c.c. syringe and a selection of serum needles or fine lumbar puncture needles with short bevels. Immediate radiographic facilities are needed, preferably with rapid development.

The approach to the joint varies with the operator The needle is driven into the articular cartilage of the head and its position checked by movements of the limb and prefe[illegible]
withdrawn just enough to allow easy [illegible]
should thereafter be prompt because [illegible]

Radioscopic control is easier than radiographic, but may endanger the gonads.

There is a place for arthrography after reduction as well as before.

Operations to Produce Reduction

If a diagnosis is made *before the child begins to walk*, formal reduction is usually necessary. The lower limbs are held increasingly abducted for some days or weeks until the heads become reduced, and they are held so until a satisfactory acetabulum has formed, usually six months or more. This early diagnosis with conservative treatment gives the best results.

In *older children* a gradual reduction can often be obtained similarly by gradual abduction, but in this case it is necessary to apply axial traction to the limbs, and very often right-angled traction to exert a medial pull on the upper part of the thigh. (This method, which is carried out with the child supine on a frame, is difficult to bring to a successful conclusion without the collaboration of a ward sister experienced in the method.) In children who have recently begun walking, manual reduction is usually possible. Thereafter, it becomes increasingly difficult, dangerous and unsatisfactory, and it should not be performed after the age of about 6 years in bilateral cases and 7 years in unilateral cases; it is of doubtful expediency after the ages of 4 or 5 years. Gentle manual reduction, if it is possible, is preferable to open reduction, which should be reserved for cases in which gentle conservative measures have failed or are known to be likely to do so for anatomical reasons. Open reduction with gentleness is better than closed reduction with force.

In *patients in their teens*, the results of attempted reduction are so unsatisfactory that it is probably better to regard the dislocation as irreducible and proceed accordingly (p. 62). Recently, extensive operations have been carried out in these and older patients by wide dissection, prosthetic replacement of the femoral head and its reduction into a deepened acetabulum at the normal level or higher. (Judet and Judet*; Merle D'Aubigné†). The expediency of these operations remains in the gravest possible doubt.

Before closed or open reduction, if the femoral head is more than slightly elevated, it may usefully be brought down gradually before operation by strapping or pin traction with the child on a Pugh bed (steeply inclined plane).

Technique of manual reduction.‡ Special apparatus.—Plaster of Paris outfit, with small pelvic rest or plaster table. Portable X-ray apparatus, with provision for rapid development.

* J[illegible]det, Jean and J[illegible]det, Robert (1950) "The [illegible]

Anæsthesia should be deep, to promote relaxation and prevent shock.

Position.—The patient is placed in the dorsal position, with the operator on the affected side and his assistant opposite.

Manipulation.—Both hips are flexed to a right angle in full lateral rotation and abduction, the assistant steadying the thigh not being treated and the pelvis. The operator flexes the affected hip to a right angle and, holding the limb by the knee, gradually abducts it at the hip joint. The operator's other hand is placed behind the great trochanter and used as a lever to lift this forward. By steadily increasing pressure upon the knee the limb is abducted until it lies flat on the table, the adductor muscles being stretched, and, to some extent, ruptured. The forward pressure upon the great trochanter pushes the head of the femur directly into the region of the acetabulum. In simple cases, during the manipulation the head of the femur is felt to slip into its socket with a click; if this does not occur, further manipulations are tried with the limb in various positions of rotation, or with the hip flexed to a greater degree, so that the femoral head is directed more downwards. When the head of the femur has slipped forward and can be felt to lie behind the femoral artery, the operation is complete and the limb ready for fixation in plaster of Paris. In most cases when the head of the femur is in the acetabulum the hamstring muscles become tight so that the knee cannot be extended The best position for fixation is tested by finding that in which reduction is most easily maintained; it is confirmed by radiography, which should show the full angle of the femoral neck, and the epiphysis exactly opposite the cartilaginous intersection at the centre of the acetabulum. Usually the best position is one with the thigh flexed and abducted to a right angle* and rotated inwards, so that the leg points somewhat backwards. Radiographs should be taken with the limb in this position with various amounts of rotation, choosing that which shows the best position of the femoral head. A thin layer of cotton wool or other padding is laid over the limb from the lower part of the calf upwards and over the lower part of the trunk, and this area is then encased in plaster of Paris bandages. In a bilateral case, if possible both hips should be reduced at one sitting, so that they may be put up symmetrically In unilateral cases it is better that the first plaster should include the thigh of the sound side, keeping it abducted at the hip. The confirmatory radiograph is repeated.

Comment.—Above all, gentleness is required for the avoidance of such complications as undue stiffness, vascular and nerve lesions, and fracture of the femur. Gentleness is achieved by patience in stretching the adductors very gradually—over a period of a quarter of an hour, if necessary

After-treatment.—The first position should be maintained for at least three months. Renewal of the plaster case at about three-monthly intervals allows gradual relaxation of the position during twelve to eighteen months, at the end of which time a good acetabulum should have formed. Radiographs are taken at intervals. Full movement and a normal gait are usually recovered spontaneously without the need of a period of weight traction.

During treatment the child is kept for the most part propped up and is encouraged to be as active as the plaster allows. To this end methods of splinting have been devised that allow a considerable range of hip movement (Bauer, Batchelor, Browne), and that have the added great advantage of being less easily soiled. So far as the hip itself is concerned, however, movement which is not about a constant centre of rotation must, we suspect, be harmful, as promoting a wide and shallow acetabulum instead of an acetabulum concentric with the head.

Technique of open reduction. **Pre-operative treatment.**—If the hip has been in plaster, it should be freed, to give the child a period of unrestricted activity in order to improve the cardio-vascular system and the density of the bones. The pathological obstruction to reduction will have been defined, so far as possible, by arthrography, and the femoral head should have been brought as low as possible by prolonged traction. Preparation should be made for blood transfusion, which preferably should be given during operation. This is of a magnitude that precludes operation on both hips at one session.

Special apparatus.—Bone instruments, including levers, mallet and a range of gouges and osteotomes; the plaster of Paris outfit, including a small pelvic support or plaster table; transfusion outfit.

Position.—With the patient supine, a sandbag is placed behind the affected hip, or, better, the table is tilted up on this side, the patient being prevented from sliding by padded supports. The limbs are independently draped

Operation.—The hip region is approached through the anterior incision of Smith-Petersen (described in detail on p. 107). In some favourable cases, excision of an inturned labrum allows the head to sink into a well-formed acetabulum; in less favourable cases, a capsular constriction may need to be slit and other obstacles to reduction must be removed, the acetabulum being cleared of its contents and deepened if necessary The head is placed in the acetabulum, and, if it seems advisable, a shelf operation (as described in the next paragraph) is carried out Sometimes capsule with synovial membrane is sewn over the head to separate the joint surfaces (Colonna*). The wound is closed, and plaster of Paris is applied, as after closed reduction. During the operation every effort should be made to preserve the blood supply of the femoral head by avoiding unnecessary injury to the capsule, especially above and behind

* Colonna, Paul C (1953), "Capsular Arthroplasty for Congenital Dislocation of the Hip A Two-stage Procedure," *J Bone Jt Surg*, xxxvA, 179

After-treatment.—Post-operative treatment, with radiographic control, is like that after closed reduction.

Operations to Maintain Reduction

Shelf operation. Indication.—Most cases of congenital dislocation of the hip are undiagnosed till walking begins. With treatment at this time it sometimes happens that the expected development of the upper lip of the acetabulum fails to take place; without it, the prospect is permanent subluxation or even re-dislocation. In such cases the shelf operation is effective, provided it is carried out over a well-reduced head. It has seldom proved satisfactory for stabilizing an unreduced head.

Pre-operative treatment.—With the hip fully reduced a plaster of Paris case is applied in the best post-reduction position confirmed radiologically. The case is split into front and back halves and the child accustomed to its use

Special apparatus.—As described for open reduction.

Position.—The bivalved plaster is removed, and the child is placed on the back on the table, which, if possible, is tilted up on the affected side with the opposite side of the trunk resting against padded supports. Alternatively a sandbag is placed behind the affected hip. The distal part of the limb is draped so that it can be manipulated by an assistant

Operation (Fig. 15).—The hip and the ilium above the acetabulum

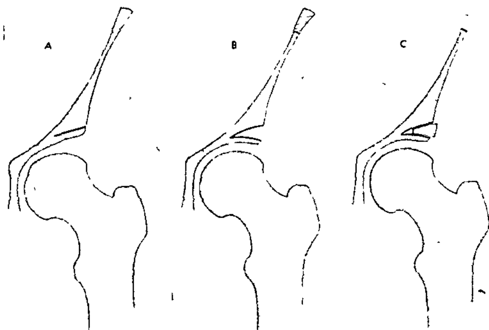


Fig. 15.—*Diagram of shelf operation for congenital dislocation of the hip.*

are exposed through a Smith-Petersen anterior incision (p. 107). If redundant capsule is stuck to the ilium by its external surface, it is separated downwards as far as the upper margin of the acetabulum, to which it is left attached. The limb is now abducted and the femoral head fully reduced. A broad gouge is driven into the lateral aspect of the ilium immediately above the margin of the acetabulum and parallel with its roof. The outlined osteo-cartilaginous flap, which includes the upper margin and adjacent part of the roof of the acetabulum, is levered downwards until the femoral head stops its further progress. A curved gap is thus left in the ilium, into which a graft cut from the upper part of the ilium (or stored bone) is firmly plugged. This is an essential part of the operation. The wound is closed and dressed, and the bivalved plaster is replaced.

After-treatment.—The position in plaster is retained for three months. The limbs are then brought to the normal position in graduated plasters without delay.

Comment.—The cartilage covering the bony acetabular rim is increased on the affected side. Consequently, in radiographs, the bony acetabular margin still inevitably looks higher on that side than the other even after operation. Mistaking this for an indication of persisting incongruity between head and acetabulum, some surgeons have tried to make sure of providing a shelf above the head by opening the joint and driving a graft into the acetabulum immediately above the head instead of bringing the roof of the acetabulum down to the head as in the operation described. The modification produces a more impressive radiological picture at the cost of an inferior anatomical correction and destruction of a part of the acetabular articular surface.

Rotation osteoclasis or osteotomy.—The normal infant has anteversion of the femoral neck of roughly 40 degrees, which diminishes so that only about 12 degrees remain in the adult. In the infant with congenital dislocation of the hip the anteversion of the upper part of the femur is greater, averaging perhaps as much as 60 degrees, but in these subjects also the amount diminishes as the child grows. Anteversion predisposes to redislocation, especially after fixation is discontinued With prolonged and careful fixation, redislocation is uncommon, but progressive subluxation is a serious problem. If, at primary reduction under careful radiographic control, it is necessary to rotate the hip medially to a great extent in order to bring the nucleus of the head into the middle of the acetabulum, excessive anteversion must be suspected, and, as the limb is released from medial rotation with successive changes of plaster or other fixation, the head must start away from the centre of the joint. In other words, a bad result, from subluxation, is inevitable unless the anteversion is corrected. There is therefore a case for anticipating this event in this particular group by a supracondylar rotation osteoclasis when the plaster is changed under an anæsthetic three months after reduction.*

* Krida, Arthur, "Congenital Dislocation of the Hip, the Effect of Anterior Distortion; a Procedure for its Correction," *J Bone Jt Surg*, 1928, x, 594

In practice, correction of anteversion has usually been carried out by osteotomy at a later stage, sometimes in the course of open reduction; often it is done so late that a really good result is out of the question. The level of the femoral osteotomy appears unimportant, but it is necessary to take steps to maintain the position of rotation, either by plating, or by driving spikes into the bone above and below and incorporating them in the overlying plaster; if the spikes are driven before osteotomy, at an angle estimated radiologically, they may be used for judging the arc. Elaborate methods of estimating the angle have been described, but probably the simplest and best is to measure clinically the amount of medial rotation of the limb that is found necessary to produce concentric reduction as shown radiographically. Methods of osteotomy are described in Chapter V, but it is well to recall here the importance in rotation osteotomy of cutting cleanly and completely through the whole bone without fracture of any part of it. Müller* has pointed out that, if the osteotomy is carried out through the shaft, the fragments tend to rotate about the linea aspera instead of the axis of the shaft unless the intermuscular septa are detached from this part of the bone, a procedure that may produce some bleeding from the deep femoral artery or its perforating branches.

Operations in Irreducible Congenital Dislocation of the Hip

Indications.—Not only in cases in which reduction is impossible by any means, but also in cases in which the results would not justify the means, operation may be required for (*a*) instability, (*b*) pain, (*c*) shortening, or (*d*) a combination of two or more of these.

(*a*) *Instability* can be considerably diminished by an osteotomy, either a Lorenz osteotomy in one of its forms or a Schanz osteotomy (p. 295).

(*b*) *Pain.* Osteotomy of a flexed hip may not only improve the gait but relieve lordosis and lumbar strain. Early pain may be relieved by manipulation. Arthrodesis is not easy and is applicable only if the opposite hip is beyond reproach; if successful it relieves local pain, may help lumbar pain by diminishing lordosis, provides stability and diminishes apparent shortening in cases with adduction—a goodly array of benefits to set against the disadvantage of stiffening a previously mobile hip; if bony union fails, however, fibrous ankylosis merely adds this extra disability to the others and the last state of the patient is worse than the first. Batchelor's combination of osteotomy with excision of the femoral head is a less uncertain procedure but does not always bring relief Neurectomies of one kind or another have been disappointing as a whole

(*c*) *Shortening.* The other troubles of congenital dislocation of the hip are such that the real shortening may be considered of little account; alternatively a patient may have an exaggerated view of its contribution to the limp and therefore be unduly hopeful of limb equalization.

* Muller, G. M., personal communication

If this is decided upon after proper consideration, the best way to achieve it, except in the squat, is shortening the longer limb.

(*d*) *Attempted relief of instability, pain and shortening by reconstruction of the joint* or arthroplasty has been mentioned on p. 57.

OPERATIONS FOR STABILIZING PARALYSED FEET

In cases of infantile paralysis, if certain muscles remain permanently paralysed, procedures may be adopted to render the foot more stable and to dispense with external support which might otherwise be required. The procedures include tendon transplantations and particularly tarsal arthrodesis. These operations must await the fullest useful recovery. This may be presumed after two years or perhaps eighteen months of efficient conservative treatment with muscle re-education, preservation of joint movement and intelligent use of splinting. A premature operation upon a bone or joint leaves a result that it is practically impossible to undo. It is undesirable also to perform these operations at too-early an age. The removal of portions of the tarsal bones in young children is apt to interfere with the growth of the foot, and makes a conclusive operation on the fully-grown foot difficult and unsatisfactory. It may be laid down as a rule that arthrodesis and similar operations should be postponed until after the age of about twelve years. Till then, it is necessary to depend upon appliances, or, if these are ineffective, upon soft-tissue operations, such as tendon transfer and muscle sliding. If, on account of ligamentous laxity or the extent of paralysis, an appliance will be necessary whether the foot is stabilized or not, it is usually possible to control the foot by means of the appliance, so that operation is unnecessary unless for the correction of deformity.

Arthrodesis of the tarsus.—The ankle is a hinge joint, normally allowing plantar flexion and dorsiflexion only. *Provided the collateral ligaments are intact*, pronation and supination are restricted to the tarsal joints, so that arthrodesis of the tarsal joints abolishes pronation and supination without interfering to an important extent with plantar flexion and dorsiflexion. Enough articular cartilage is removed from the joints to bring bony surfaces into contact in good position so that bony ankylosis may ensue.

Indication.—Besides being used as a stabilizing operation to abolish pronation and supination when uncontrolled because of paralysis, tarsal arthrodesis may be used for the permanent correction of bony deformity or for the relief of painful tarsal arthritis in which conservative methods have failed.

Methods.—Rarely, if ever, should arthrodesis be performed upon the subtalar (subastragaloid) or the mid-tarsal joint* alone; [illegible] ankylosis of both should be the aim. Many methods of achieving [illegible]

* The mid tarsal joint comprises the talo-navicular (astragalo-scaphoid) and calcaneo-cuboid [illegible] Some anatomists call it, more correctly, the transverse tarsal joint [illegible]

have been devised; the standard method in this country is Dunn's arthrodesis (Fig. 17), which will be described here. Removal of the navicular (scaphoid) bone, which is inherent in this operation, has the merits of simplifying it and of allowing backward displacement on the talus (astragalus) of the remainder of the foot, an advantage if the



Fig. 16.—Tarsal arthrodesis: skin incision.

prominence of the heel is poor or the soleus and gastrocnemius are weak.

Lambrinudi's arthrodesis (Fig. 18) also will be briefly referred to because it is extremely valuable if a complicating foot-drop needs correction. This operation is carried out in such a way that, when the talus is fully plantar-flexed and cannot flex any further because its posterior tubercle has come into contact with the tibia, the foot as a whole is in the best position; that is to say plantar-flexed only enough to allow for the heel of the shoe. Some like to plan this operation from a lateral radiograph of the fully dropped foot.

Special instruments.—Small bone levers, gouges and osteotomes of various sizes, a mallet and the apparatus required for the application of plaster of Paris

Position.—The patient is placed on the sound side, the affected foot lying on its inner aspect which is supported by a sandbag.

Dunn's arthrodesis of the tarsus.—An Esmarch's bandage is applied to the calf as a tourniquet The incision starts about three fingers' breadth above the tip of the lateral malleolus, immediately behind the shaft of the fibula, and passes downwards before curving forwards beneath the lateral malleolus and extending to about the mid-point of the fifth metatarsal bone (Fig. 16). The peroneal sheath is opened, and the peronei, longus and brevis, are either retracted forwards or, preferably, divided at different levels. The full thickness of the flap outlined by the skin incision is dissected up from the

periosteum and the capsular ligaments; during this procedure the front of the ankle joint may be opened, an event of no practical importance. The subtalar articulation is opened and the knife is carried forwards and upwards so as to open also the talo-navicular articulation. The assistant inverts the foot, and the strong interosseous ligament between the talus and calcaneum is divided; that

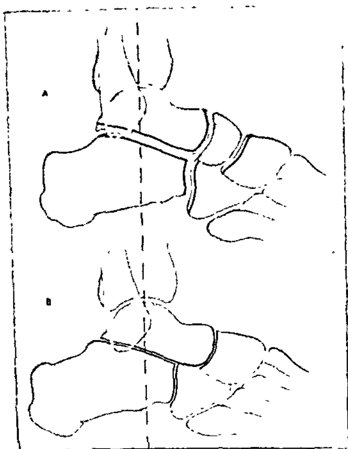


Fig. 17.—Diagram of Dunn's tarsal arthrodesis.

A, Articular cartilage removed and navicular (scaphoid) bone excised. B, Other bones of foot displaced backwards on the talus (astragalus), closing the gap left by the absent navicular bone.

part of the foot which lies distal to the talus can be supinated through 180°, so that both the lower articular surface of the talus and the upper articular surface of the calcaneum come to face distally.* The navicular bone is removed. The following joint surfaces are denuded of articular cartilage by means of gouges and osteotomes: the lower surface of the talus, the front of the talus, the back of the three cuneiform bones, the upper surface of the calcaneum, the front of the calcaneum, and the back of the cuboid bone. That part of the foot lying distal to the talus is rotated through 180°, so as to assume once more its normal orientation, and is displaced backwards so that the raw posterior surface of the cuneiform bones lies in contact with the

* Failure to expose the joints fully by opening out the foot in this way has led to incomplete removal of articular cartilage and failure of the operation.

anterior rawed surface of the talus. The denuded surfaces should now lie snugly, with the foot plantigrade. The divided calcaneo-fibular part (middle fasciculus) of the lateral (external lateral, fibular, collateral) ligament of the ankle is repaired with catgut, and it is customary to unite the peronei, whether paralysed or not, if they have been divided and unless they are to be transplanted. The flap is sewn back in place

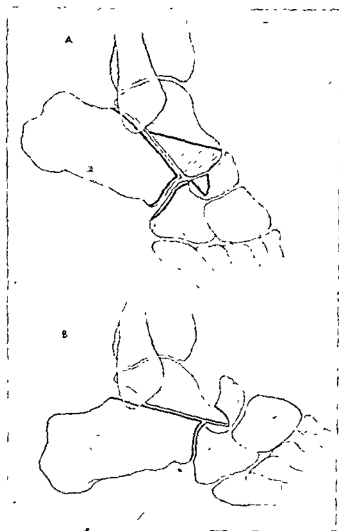


Fig 18.—Diagram of Lambrinudi's tarsal arthrodesis.

with a few subcutaneous stitches and with skin sutures, without drainage. Dressings and cotton wool are applied, and the foot and ankle are fixed in plaster of Paris, with meticulous care, in the right-angled and plantigrade position, with special pains to avoid a varus tilt or a downward convexity of the lateral border. The tourniquet is then removed. (A domette bandage over the cotton wool helps to maintain the position during plastering but may embarrass the circulation later.)

After-treatment.—The usual care of a limb in plaster must be observed (p. 82). At the end of two or, usually, three weeks the plaster case is removed and the stitches are taken out. Often some sloughing of the skin edges is found, and this must not be thought to signify infection. The wound is covered with a tulle gras patch and a fresh plaster case is applied, without a window (which may allow varus deformity). Walking is encouraged in the plaster, which is retained till the end of four months from the operation, when it is removed and radiographs are taken. If clinical and radiological examinations leave real doubt about bony ankylosis, a further plaster is applied and retained for six weeks, and then the examination is repeated.

Lambrinudi's arthrodesis of the tarsus.—The earlier stages of this operation are identical with those of Dunn's arthrodesis. The navicular bone is not removed. The following articular surfaces are denuded of cartilage: the upper and anterior surfaces of the calcaneum and the posterior surface of the cuboid bone. A wedge of predetermined size is removed from the antero-inferior part of the talus, leaving a flat raw surface which can be opposed to that on the upper aspect of the calcaneum when the talus is plantar-flexed. A notch is made in the lower part of the navicular bone from behind, and the pointed front of the talus is forced into it by displacing the rest of the foot backwards. Closure and fixation in plaster are carried out as in Dunn's arthrodesis, except that the foot is fully dorsiflexed. Special care must be taken to ensure that this position and particularly backward displacement are maintained; otherwise the point of the talus may become disengaged from the notch in the navicular bone. (If, after closure, a depression is palpable on the dorsum of the foot immediately behind the navicular bone the point of the talus is probably still satisfactorily in its notch.)

After-treatment.—A few days after operation lateral radiographs should be taken, to ascertain that the notch in the navicular bone has not become disengaged from the pointed front of the talus. Otherwise the after-treatment is as for Dunn's arthrodesis.

Comment.—It does not seem to be recognized that, unless the anterior ligament of the ankle is unimpaired, Lambrinudi's arthrodesis will fail to cure drop-foot, which will continue to take place by hinging at the posterior articular margin.

Elmslie's operation for paralytic talipes calcaneus.—This is a combined operation, performed in two stages six weeks apart.

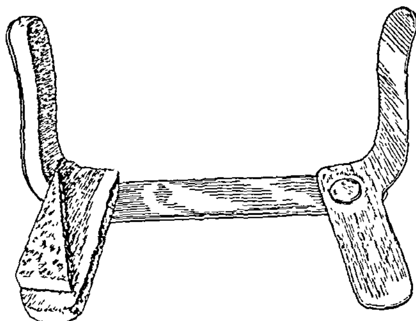
Stage 1 consists in: (*a*) Steindler's operation for stripping the under surface of the calcaneum (p. 166); and (*b*) talo-navicular arthrodesis, performed through a medial incision, with downward retraction of tibialis posterior and separation of the dorsal structures. The foot is fixed in plaster of Paris in a position of strong dorsiflexion.

Stage 2, carried out six weeks later, comprises: (*a*) posterior subtalar arthrodesis, a small wedge being removed with its base posteriorly; (*b*) tenodesis of part of the tendo Achillis (p 162); and

(*c*) transplantation of the tendons of flexor longus hallucis, flexor longus digitorum, peroneus longus and peroneus brevis into the tendo Achillis just above its insertion. These procedures are all carried out through a four- or five-inch vertical incision along the medial border of tendo Achillis. *The foot is fixed in plaster of Paris in about twenty* degrees of plantar flexion for three months.

OPERATIONS FOR CONGENITAL TALIPES EQUINO-VARUS

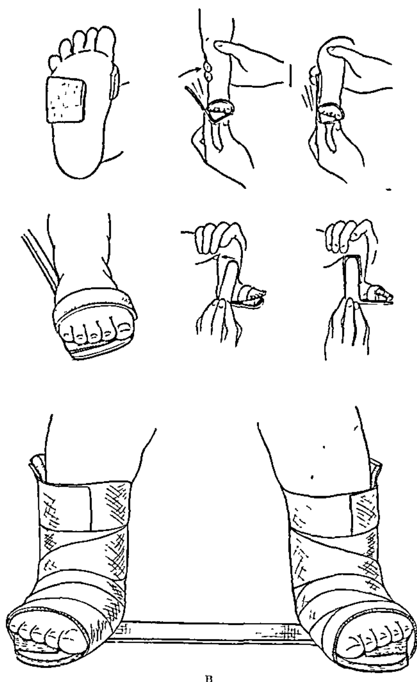
The first principle of the treatment of congenital talipes equino-varus is to produce full anatomical correction and to maintain this by persuading the previously overstretched peronei to take on their normal function. Recurrence is the bugbear, and the greatest cause of recurrence is failure to achieve full correction before walking begins. With full correction, standing and walking tend to combat the deformity, and the peronei readily take up their duties. With less than full correction, weight-bearing tends to promote deformity, and the peronei fail. Consequently, it is very important, if possible, to obtain full correction before walking starts, and therefore to begin treatment without delay. Correction should be secured, if possible, by gentle manipulation and splinting, without any cutting. If a cutting operation becomes necessary, it should preferably be confined to the soft *tissues, and no operation should be carried out to correct* the equinus deformity until the varus has been totally abolished: the purchase of the tendo Achillis and the posterior capsule is necessary in applying the least force to control the varus deformity. If, other methods having failed, a bone operation is essential, it should be postponed until growth of the foot is practically complete: although the immediate



A

results of bone operations upon the young foot may appear admirable, the late results are often deplorable.

1. Manual methods of correction.—In the newly-born child, the feet should be manipulated firmly but not forcibly into as good a position as possible and strapped there, manipulation and restrapping being carried out weekly by an enthusiast thoroughly conversant with the method. In a month or two the child's feet will be big enough



B

Fig. 19.—Denis Browne's hobble splint for congenital talipes equino-varus.
A (*facing*), The splint, consisting of two footpieces bolted to a crosspiece, the right footpiece is shown padded with adhesive felt. B, The splint applied in a bilateral case

for Denis Browne's hobble splint (Fig. 19) to be efficiently used. This is much the most effective form of splinting, probably because the child does its own manipulation by "auto-assisted" movements, so that correction is active and not passive. Every infant in arms marks time, and the hobble part of the splint sees to it that with each beat the depressed foot is inverted and the elevated one everted. As the varus deformity becomes thus corrected, the toes of the splint are turned out increasingly, so that the same movement promotes dorsiflexion. Each footpiece, padded with felt, is separately applied to its foot; (1) a felt pad is placed under the outer side of the foot; (2) the instep is securely strapped to the splint; (3) the ankle is strapped down, in such a way that the front of the ankle is tethered to the heel of the splint; (4) the *leg piece, previously ignored, is brought up to the side of the leg and* strapped into place; (5) the strapping is covered with bandages; and, (6) the cross-piece between the splints is applied with the required degree of lateral rotation.

Should progress be unduly slow, it has been customary at about six months to manipulate the feet under an anæsthetic, and fix them just short of the corrected position in padded plasters, which must include the knees in order to control rotation and prevent the splints from being kicked off. Alternatively, half-circumference plaster splints may be applied with soft bandages reinforced with elastic adhesive strapping, and in this case the knees are left free. Traditionally the *plasters are retained for six weeks, but probably this is too long.*

The present tendency is to avoid these forcible manipulations, and to depend, in resistant cases, upon graduated or wedged plasters, such as those described by Kite.*† Serial plasters are applied without manipulation, first with varus corrected as much as possible and later with equinus corrected. Frequent change of plaster may be avoided by weekly wedging, first laterally to correct varus and then at the heel to correct equinus.

When walking begins, the patient is carefully watched for recurrence, and the use of splints at night is continued.

Method of manual correction.—The surgeon attempts to unfold the foot with his hands, taking each element of the deformity in turn. First he stretches the sole to correct the cavus deformity as much as possible. Then the front of the foot is grasped with one hand, the heel with the other, and the front of the foot is steadily abducted and everted. Finally, in this position of pronation, the foot is steadily dorsiflexed until it passes beyond the right angle.

2. Soft tissues operations.—These—a confession of failure to produce correction by manipulative means—should be postponed if possible till the age of five or six years, or preferably later. The operations chosen will depend upon the predominant deformity,

* Kite, J. H. (1930). "Non-operative Treatment of Congenital Clubfeet. A Review of One Hundred Cases," *Southern Medical Journal*, xxiii, 337

† Fripp, A. T. (1951), "The Relapsed Club Foot," *Proc. R. Soc. Med.*, xliv, 873 (Sect. Orthopædics 55)

always bearing in mind that the tendo Achillis must not be lengthened until all other elements in the deformity have been corrected.

(*a*) **Cavus deformity.**—The soft tissue operation for this is Steindler's operation, described on p. 166.

(*b*) **Varus deformity.**—Granted little bony change, varus deformity is corrected by the operation of talo-navicular capsulectomy or capsulotomy, described on p. 170. Although the immediate results of this operation may be brilliant, the remote results have been disappointing in the past, because the peronei of a foot demanding it are no longer able to take on their task. Consequently this operation should probably be followed always by transfer of tibialis anterior to the outer side of the foot (p. 154), usually after about six weeks.

(*c*) **Equinus deformity.**—This may be corrected by the operation of lengthening the tendo Achillis (p. 187), supplemented, if necessary, by posterior capsulotomy of the ankle through the same incision.

3. Bone operations.—These are, as stated, a last resort when simpler means have failed to secure and maintain correction. Such older operations as wedge tarsectomy or excision of tarsal bones left a very disabled foot, and tarsal arthrodesis is very much to be preferred. A successful operation provides a serviceable plantigrade foot, with no fear of recurrence provided that the operation is postponed, as already advised, to about the age of twelve when most growth of the foot has ceased. The most generally useful form of tarsal arthrodesis is Dunn's (p. 64). Alternatively, if there is much equinus deformity, Lambrinudi's arthrodesis (p. 67) may be used, but it gives mid-tarsal fixation less surely.

OPERATIONS FOR PES CAVUS

The operations that may be carried out are: *for the stiffness*: manipulation; *for the claw toes*: if supple, tendon transfer from the flexors to the extensor expansions (p 157); if stiff, arthrodesis of the interphalangeal joints; *for the high arch*: if bony deformity is slight, Steindler's operation (p. 166); if bony deformity is important, tarsal arthrodesis (p. 63).

The treatment is governed particularly by the symptoms, the age of the patient, and the underlying cause.

The symptoms.—Pes cavus is not always a serious inconvenience, especially if the foot and its toes are kept supple. Sometimes it gives symptoms of footstrain—chronic tarsal or plantar pain, provoked more by standing than by walking and relieved by rest—or of chronic sprain of the ankle; these troubles are relieved by manipulation under an anæsthetic and subsequent physiotherapy, notably exercises. Often the clawed toes are the main source of trouble, from pressure, especially if they are stiff; again, manipulation and physiotherapy may help, but often it is necessary to straighten the toes—by tendon transfer if

they are supple, or by arthrodesis if they are stiff. The height of longitudinal arch itself often causes trouble, sometimes because of the difficulty in getting shoes to lace or strap across the instep, but more often because the whole body weight is concentrated on small areas of the sole which consequently become the site of painful callosities, especially under the metatarsal heads, where the trouble is aggravated by incompetence of the toes. In such cases, Steindler's operation is of value if bony deformity is not too great, but the only sure method of flattening the foot and keeping it flat is the performance of a tarsal arthrodesis, preferably Dunn's.

The age of the patient.—*In children*, much can be done to curb progress—and even bring improvement—with exercises, stretching and splinting, so that operation is seldom indicated, except occasionally a tendon transfer of toe flexors to extensor expansions, or a plantar fasciotomy (usually Steindler's operation). Subcutaneous tenotomy of the toe extensors proves tempting, but is of little or no value. *In adolescents*, operation should still be considered an adjunct to conservative methods. Tendon transfer of the toe flexors to the extensor expansion is of special value at this age if the toes have not stiffened. Steindler's operation can help in so far as tightness of the structures of the sole is out of proportion to bony deformity. When this is severe, arthrodesis is required. *In adults*, conservative treatment is still of value in preserving mobility, but of little help in other respects except in palliation. If palliation fails, or is unduly irksome, operation may be indicated. Often the toes are too stiff for a successful tendon transfer and can be straightened only by arthrodesis. Steindler's operation can be expected to give less improvement than in adolescents but is sometimes a useful preliminary to tarsal arthrodesis.

The cause of the deformity.—(*a*) Congenital: the cavus is part of congenital talipes equino-cavo-varus, the treatment of which is considered above. (*b*) Idiopathic. the progress and consequent disability vary greatly. (*c*) Familial. this resembles idiopathic, but the prognosis may be guessed by the experience of other affected members of the family. (*d*) Neurological and myological: in poliomyelitis, other defects influence a decision about operation; in spina bifida, sensory disturbance may be an important consideration; in systemic neuro-muscular diseases, the prognosis often influences a decision—for instance, peroneal muscular atrophy often ceases to progress in the teens, so that operation may be indicated, whereas pseudohypertrophic muscular dystrophy is too relentlessly progressive to make operation often worth while.

OPERATIONS FOR HALLUX VALGUS AND HALLUX RIGIDUS

Indications and contra-indications.—Almost the only indication for operation in hallux valgus or hallux rigidus is pain, and it is important to be sure that this is in fact the consequence of trouble at

the first metatarso-phalangeal joint, and not of an associated "transverse flat foot" for instance. Operation for the sake of appearance alone is usually unwise, because the cosmetic result is necessarily imperfect and because a painless toe may be converted into a lastingly painful one. Patients who are able to obtain relief by conservative means should be encouraged to do so. Many special operations have been devised for children, but the results of operation before growth finishes have been deplorable, and recurrence has been almost or quite invariable. A new attempt is being made by modifying epiphyseal growth of the first metatarsal bone by stapling.*

Pre-operative treatment.—If acute or subacute symptoms are present they should be allowed to subside with rest. The patient should become proficient in exercises for the intrinsic muscles of the feet, practising the combination of interphalangeal extension with metatarso-phalangeal flexion of all the toes.

Varieties of Operation

(1) Hallux valgus.—Discontent with the anatomical and functional results of operation has led to a multiplicity of procedures, but only a few will be considered. Hallux valgus implies not only valgus deformity of the great toe, with the formation of an exostosis and bursa over the first metatarsal head, but commonly also varus deviation of the first metatarsal bone, which may be relatively short.† Operations for realignment of the metatarsal involve a long convalescence and have been decidedly disappointing; first metatarso-cuneiform arthrodesis has probably succeeded better than osteotomy, which is most disappointing though possibly improved by temporary internal fixation. Any operation that materially shortens the metatarsal tends to promote "transverse flat foot" with undue pressure on the second metatarsal head of such severity as to defy relief. Excision of the exostosis with some of the overlying bursa is no more than a temporary expedient if angulation remains. This is corrected usually by an operation that shortens the digit without abolishing joint movement —an arthroplasty in the loose sense of an operation designed to preserve or restore movement. Either the proximal articular surface may be removed or the distal. Removal of the whole metatarsal head shortens the first metatarsal bone too much and may cause the disastrous result already referred to; this operation should be abandoned wholly, or at all events in those with a short first metatarsal bone. *Resection of the head*—that is to say removal of part of it—with careful preservation of the sesamoid surface gives good anatomical results except in those with pre-existing unduly short metatarsals or pronounced transverse flat foot, but the limited removal of bone may lead to *stiffness*. Consequently, the present tendency is to remove the proximal part of the

* Ellis, V. H., "A Method of Correcting Metatarsus Primus Varus: Preliminary Report," *J. Bone Jt Surg.*, 1951, xxxiiiB, 415

† By *analogy* with the metatarsal bone of the thumb-like great toe of the anthropoid ape, the short varus first metatarsal has been called metatarsus atavicus; it is graciously considered to be commoner in the female sex and has been considered, almost certainly erroneously, a cause of hallux valgus.

proximal phalanx and to leave the metatarsal head intact but for its exostoses. This operation was devised by Davies-Colley* for hallux flexus, but he made no mention of trimming away the exostoses as subsequently described by Keller,† whose name the operation now bears. The interposition of soft tissue—such as the bursa in Mayo's operation of excision of the metatarsal head—seems to make little or no difference to the final result.

(2) Hallux rigidus.—Usually the same operation is performed as for hallux valgus; but a painless, mobile joint is obtained less often than in hallux valgus. A few surgeons therefore prefer an arthrodesis, fusing the metatarso-phalangeal joint in the best position for function, namely slight dorsiflexion; their patients must accept some three months of plaster fixation and a stiff joint that, though itself painless, is not consistent with normal function of the foot as a whole.

Special instruments.—Rugine, small bone levers, osteotomes and mallet. Excision of the base of the proximal phalanx calls additionally for a fine saw and bone cutting forceps. A file and bone wax are refinements. An Esmarch's bandage is used as a tourniquet.

Position.—The patient is placed on his back, the lower limbs rolling naturally outwards, and a sandbag is applied to the sole.

Resection of the first metatarsal head.—The skin and superficial fascia are divided, preferably by a two-inch longitudinal incision on the dorso-medial aspect of the joint. After the skin edges have been slightly freed, the incision is deepened to bone and into the joint. The soft tissues are cleared from the metatarsal head and neck, which may be elevated by bone levers. The exostoses and the distal half of the head are removed with an osteotome and mallet in such a way as to leave a rounded extremity (Fig. 20A) with as little encroachment as possible upon the under surface, which is in contact with the sesamoid bones in the two tendons of insertion of the flexor hallucis brevis. The bone fragments are removed by forceps and scalpel, the assistant applying traction to the toe in order to open up the joint space. The adventitious bursa, or part of it, is removed, care being taken that enough thickness of subcutaneous tissue remains. The soft tissues and skin are separately closed without drainage. Gauze and cotton wool are bound in place with a bandage which is applied in such a way as to hold the great toe in a straightened or even slightly varus position and to maintain as much transverse arch as possible.

After-treatment.—Exercises for the intrinsic muscles should be resumed; but, in the writer's opinion, early passive movement, except perhaps gentle distraction, is undesirable. The stitches are removed after about ten days. The patient begins walking at the end of a fortnight in a roomy shoe, having a soft upper but preferably a stout sole. Corrective, but not unduly restrictive, strapping is applied to

* Davies-Colley, N. "On Contraction of the Metatarso-phalangeal Joint of the Great Toe (Hallux flexus) With Cases," *Trans. clin. Soc. London*, 1887, xx, 165.

† Keller, W. L., "The Surgical Treatment of Bunions and Hallux Valgus," *N.Y. med. J.*, 1904, lxxx, 741.

the toe and transverse arch, and is retained for about eight weeks. A return to ordinary activities should be slow, and graduated over some twelve weeks in people with active occupations.

Resection of the proximal phalanx of the hallux, with excision of the metatarsal exostoses.—A two inch dorso-medial longitudinal incision is made through skin and superficial fascia. The skin edges are slightly undercut, and the incision is deepened to bone and into the joint. The exostoses on the head of the metatarsal bone are freed of soft tissue and excised so as to leave a flush surface (Fig. 20B). Small bone levers are passed round the base of the

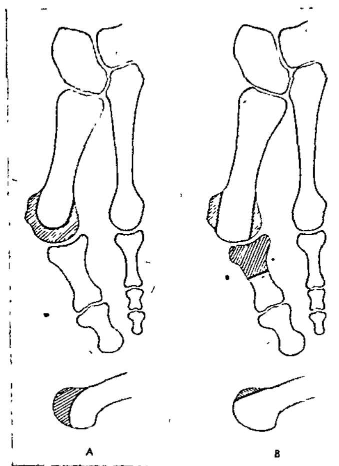


Fig. 20.—Diagram of operations for hallux valgus.
A, Resection of metatarsal head. B, Excision of proximal half of proximal phalanx, with excision of exostoses.

phalanx, and this is freed from soft tissues and dislocated. This part of the operation may be tedious, especially if there is much lipping, because care must be taken to avoid division of the flexor pollicis longus, which lies between the bone and the levers. When dislocation has been achieved the base of the phalanx in seized with lion forceps, or caught in a sharp hook,* and so steadied while the process of freeing the

* Not recommended if bloodshed is to be confined to the patient.

proximal half of the bone is completed; it is then divided at its middle by means of a Gigli saw or a hack saw. Any angles remaining are trimmed with bone forceps and all bone chips are removed from the wound, which is then closed and dressed in the manner described for operation on the metatarsal head.

After-treatment.—As for resection of the first metatarsal head.

OPERATIONS FOR HAMMER AND CLAW TOES

This condition affects usually the second toe; the proximal interphalangeal joint is more often troublesome than the distal. The best operation for straightening the proximal interphalangeal joint is an arthrodesis, because bony ankylosis makes recurrence impossible. A hammer condition of the distal interphalangeal joint is often more satisfactorily treated by amputation of the distal phalanx, because often the toe is long, there is a corn at its tip, as well as over the joint, and the nail is deformed; moreover bony ankylosis is not easily promoted at this joint. If a hammer second toe is associated with considerable hallux valgus both conditions must be corrected at the same operation. (A clawed minor toe, usually the second or third, may undergo pathological dorsal dislocation at the metatarso-phalangeal joint; it should be treated, not as a hammer toe, but, if operation is needed, by resection of the corresponding metatarsal head.)

Arthrodesis of proximal interphalangeal joint for hammer toe.—
Special instruments.—Small cutting (Fig. 21) or gouge forceps (Fig. 80) and small burr (Fig. 22).

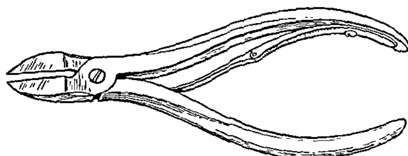


Fig. 21.—Small bone cutting forceps.



Fig. 22.—Paton's burr.

Operation.—The corn which almost always crowns the joint is excised through a transverse elliptical incision. The proximal arc is deepened to bone, to divide the dorsal expansion and the periosteum of the proximal phalanx near its junction with the articular surface.

The joint is thus opened. The lateral ligaments are divided, and the articular surfaces separated. Each is cleared of soft tissues round its margins and denuded of cartilage. To promote bony ankylosis it is well to cut a cylindrical peg on the distal extremity of the proximal phalanx and insert this into a burr hole in the base of the middle phalanx (Higgs's operation). The dorsal expansion is repaired with a single mattress suture of fine catgut, and the elliptical skin incision is united to form a transverse linear wound. A supporting dressing is applied as follows: two strips of gauze are used, the first to form a

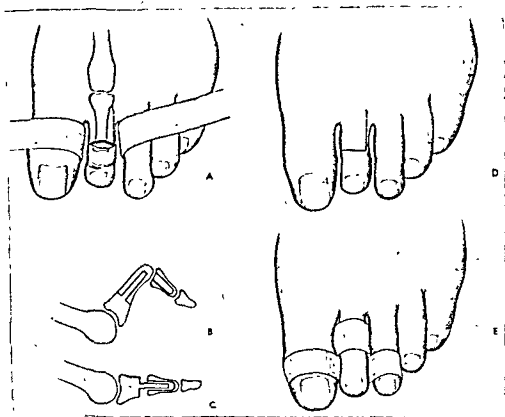


Fig. 23.—Diagram of Higgs's so-called " spike " arthrodesis for hammer toe.

A, Skin incision (the longitudinal stem shown by a broken line facilitates the operation and is recommended). B, Peg cut in proximal phalanx, and socket burred in distal phalanx. C, Peg introduced into socket *D*, Closure *E*, Method of dressing.

loop over the dorsum of the proximal phalanx, the second to form a loop under the plantar surface of the middle and distal phalanges; wool and a bandage are applied, care being taken not to apply pressure to the tips of the toes.

It is important not to fix the joint in hyperextension, or even straighter than its neighbours.

After-treatment.—Weight should not be borne on the foot for a fortnight. The stitches are removed then or a few days earlier, and a splint of ribbon gauze and benzo-mastische is worn for a further fortnight.

Arthrodesis of other interphalangeal joints.—The interphalangeal joint of the hallux and the distal interphalangeal joints of the other toes are less satisfactorily dealt with by Higgs's operation of fashioning a peg and socket, and it is also very tedious if several joints have to be dealt with, as in pes cavus. It is better to use transfixion wires.

Special instruments.—Small bone cutting and gouge forceps. Special Kirschner wires 2 mm. thick, 3 in. long and pointed at each end. Cannulated hand-chuck to take these.

Operation.—After the articular surfaces have been denuded, the wires are introduced axially across them and through the phalanges, being cut short with about ½ in. protruding from the end of the toe. Care must be taken to avoid distraction and to try to impact the cut bone surfaces.

After-treatment.—Little weight-bearing is allowed till the wires are removed at the end of three weeks. Preferably, walking plasters with slabs supporting the toes should then be used for a further three weeks.

Tendon transfer for claw toes.—Supple claw toes, as in some cases of pes cavus, can be treated by transfer of the long flexor tendons to the dorsal expansion (Girdlestone's operation) (page 157).

INGROWING TOE-NAIL AND ONYCHOGRYPHOSIS

If an ingrowing or a thickened toe-nail cannot be controlled by simple measures, such as those of the chiropodist, it may be treated by avulsion of the nail or by removal of the whole nail-bed. An ingrowing nail may alternatively be treated by Willett's operation.

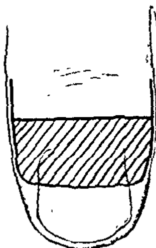


Fig. 24.—Excision of nail bed: skin incision after avulsion of nail; the hatched area of skin is removed.

Avulsion of the nail.—Under anæsthesia, one blade of a flat-bladed pair of forceps is pushed well down under the nail, which is grasped, twisted free at the sides and then pulled out. As the nail bed is exceedingly sensitive it is imperative to use a greasy dressing, such as tulle gras. Unfortunately the new nail is likely to grow in the same way as the old one and recurrence is common.

Willett's operation.—This aims at the production of a flat scar along that side of the nail which tends to grow in. A tenotome is passed in at the side of the base of the nail, deep to the skin, under-cutting it to a width of half an inch. The tenotome is then worked forwards to beyond the tip of the nail, thus raising a flap of skin half

an inch wide along the whole of the nail margin; this flap is cut off at its base and the raw area allowed to heal by granulation.

Extirpation of nail-bed.—This is a much more radical and satisfactory procedure than Willett's. Any sepsis is controlled by the usual measures, supplemented, if necessary, by avulsion of the nail at a preliminary operation. An Esmarch's bandage is used. The skin is divided as in Fig. 24. The proximal flap and the edges of the lateral incisions are raised from the underlying nail-bed. This, recognizable by its toughness, is dissected with meticulous thoroughness right down to periosteum and across the whole dorsal semicircumference, with special care at the proximal angles. Enough of the tip of the distal phalanx—usually about the distal half—is removed to allow closure without tension. The necessary suture of a long flap to a short one leaves a very untidy appearance, which Nature soon rectifies. If any nail-bed is left behind very troublesome spicules will grow through the skin. (A hexagonal excision gives a neater immediate appearance, but perhaps less direct access to the proximal corners.)

ISCHÆMIC CONTRACTURE OF THE FLEXOR MUSCLES OF THE FOREARM

In ischæmic contracture the fibres of the affected muscles have undergone aseptic necrosis and have disappeared, being replaced by fibrous tissue. Usually the pronator teres (p. radii teres), flexors of the carpus and flexores sublimis and profundus digitorum are thus affected, and the forearm is held pronated with the wrist and fingers flexed. There is often, also, partial involvement of the median and ulnar nerves, so that the sensation of the hand is imperfect; and the intrinsic muscles may be involved.

The first task is to assess the power remaining in the muscles of the forearm and hand. Usually the extensor group in the forearm is fairly strong. If so, and if the fingers and wrist are mobile, or can be made mobile, some function can be restored to the fingers after reasonable correction of deformity. The fingers will then be capable of extension by the action of extensor digitorum (e.d. communis), and of flexion by a trick action even if no power remains in the finger flexors. The trick action is brought about by dorsiflexion of the wrist, which tightens the tendons of the inert flexor muscles, thus pulling the fingers into flexion. Nothing should be done that might prejudice this trick action unless it can be replaced by something better.

Methods of diminishing deformity without destroying trick flexion of the fingers are: (1) elongation of the flexor tendons, with anterior capsulotomy of the wrist if necessary, (2) a muscle slide operation, releasing the origins of the flexor muscles (p. 168), (3) shortening the forearm bones, (4) removal of carpal bones. Any tendon lengthening or muscle slide operation should not be enough to abolish all flexion contracture in the fingers or to diminish any power that may remain in

the flexor group of muscles. Bone shortening, whether in forearm or carpus, inevitably weakens the extensor muscles, and excision of carpal bones may interfere unnecessarily with wrist movement and therefore with trick flexion of the fingers.

If the extensor muscles have survived it may perhaps be justifiable to transplant the carpal extensors into the digital flexor tendons, but this makes it necessary to perform also an arthrodesis of the wrist and carpus, so sacrificing trick flexion of the fingers. This is of no consequence *if the transplant succeeds.*

CHAPTER III

OPERATIONS ON JOINTS

By P. JENNER VERRALL

Revised by V. H. ELLIS*

Introduction.—The object of surgical operations is the restoration or maintenance of function; either in the widest sense by the preservation of the life of the patient, or more narrowly by increasing the use of the limb. Paradoxically in the case of joints this object may best be attained by fixation and the establishment of a bony ankylosis to ensure stability or relief from pain.

In past times operations on joints were largely restricted to attempts to eliminate infection by drainage or excision, and while such procedure may still be required, prevention and treatment of such infections by other means has greatly lessened their frequency. At the same time the perfection of aseptic technique, of the highest importance in dealing with synovial cavities, has rendered joint operations much less hazardous.

ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

Morphology.—The earliest sign of joint formation in the primitive limb-bud is the appearance of a thickening of the mesenchyme between the masses which will subsequently develop into bones. At first this is a simple joint-plate and in synarthroses all the intervening material persists. In amphiarthroses, however, such as the intervertebral discs and symphysis pubis, there is early formation of a cleft, which becomes filled with a mucoid substance. In diarthroses a full cavity develops, which may be multiple in those joints where there are intra-articular structures, the latter representing a persistence of the intervening substance between two separate cavities. The surroundings of the cavity form two layers of which the outer becomes the primitive capsule and the inner the early synovial membrane. In the course of development of diarthroses this primitive capsule becomes thin to vanishing point on those aspects of the joint on which no ligamentous strain is imposed and the range of movement is checked by other means, while other parts become thickened to form special ligaments. In many cases these thickenings are morphologically detached portions of muscles which originally crossed the joint and have, in the course of evolution, ceased to do so, gaining new insertions

* Mr V. H. Ellis died on September 15th, 1953, aged 52, and before he had an opportunity to read the proof of this section which he had revised.

and leaving the distal part of their tendons as ligaments. The knee and shoulder afford good examples of this. In the former the original capsule is almost non-existent, the anterior capsule consisting of the tendons of the vasti, the ligamentum posticum Winslowii being a development of the semi-membranosus, and the internal and external lateral ligaments being detached tendons of the adductor magnus and peroneus longus respectively. In the shoulder the coraco-humeral ligament represents the upward extension of the pectoralis minor. Ligaments may also develop from the sheaths of muscles, e.g., the ilio-femoral from the iliacus on the inner and the gluteus minimus on the outer side. These specialized structures indicate exactly where strain may be expected and their integrity must be respected in reconstructive operations.

Component parts of joints.—*The articular ends of the long* bones are formed of spongy bone which, as the joint is approached, becomes much denser, and a thin plate is formed. Over this lies the articular cartilage, hyaline, with no perichondrium or covering of synovial membrane. The elasticity of this cartilage is of primary importance as a shock absorber, and no other substance can replace it in this respect. For this reason, and also because it is a non-expendable tissue, i.e., one which is never fully replaced after injury, the greatest care must be exercised to avoid damaging it in the conservative surgery of joints. Such operations as that of Nicola on the shoulder, or the elevation of the external articular surface of the femur to prevent outward dislocation of the patella, have this definite disadvantage.

Articular cartilage contains no blood-vessels and no nerves, its nutrition being supplied partly from the underlying vascular bone, but mainly from the synovial fluid. When a joint is injured, either a synovial fringe becomes temporarily attached to the lesion, or a "pannus" grows in from the vascular periphery. By this means repair by fibrous tissue is achieved. Early movement of the joint during the process destroys this delicate tissue; it must be constantly re-formed and recovery is delayed. Failure of these temporary structures to disappear when they are no longer needed is a potent source of intra-articular adhesions.

Fibro-cartilages may be intra- or extra-articular and may represent either the remains of a primitive division of the joint or the vestiges of structures that have vanished during evolution, e.g., that of the sterno-clavicular joint Until recently it was thought that they had no nerve supply but the contrary has now been clearly proved, and sensory nerve-endings can be shown *microscopically in special* preparations.

Synovial membrane and fluid.—The synovial membrane lines the joint and covers all its surfaces, except those occupied by articular, hyaline or fibro-cartilage. It is attached to the bones at the margin of the articular cartilage and is a thin vascular membrane lined with

flattened cells. It contains nerves, both medullated and non-medullated often accompanying the vessels and furnished with different types of nerve endings. Some of these convey pain sensation but they are not evenly distributed, so that only parts of the synovial membrane are sensitive when pricked or pinched. No doubt many of the nerves are associated with vasomotor activities.

The synovial membrane has great powers of regeneration so that within a few months of an apparently complete synovectomy a new membrane may be formed. It frequently undergoes hypertrophy from inflammation and may show metaplasia as in chondromatosis.

The synovial fluid is partly a dialysate of blood plasma, but also contains mucin which is probably derived from the disintegration of the superficial layers of articular cartilage. The viscosity caused by the mucin renders it ideal as the lubricant for slow-moving joints. The fluid also contains substances which act as nutrients for the superficial layers of articular cartilage, even when a portion of this lies completely loose in the joint. In addition it has some slight antiseptic powers by virtue of its content of lysozyme.

Normally joints contain only a small quantity of fluid; when this is increased, as in synovitis, its mechanical and lubricant characteristics are interfered with.

Mechanics of joints.—In joints such as the sacro-iliac or symphysis pubis very little movement is contemplated, but the small range permitted is of primary importance. The surfaces are irregular, and the integrity of the joint depends on strong ligaments in which a certain amount of elastic tissue is incorporated. These joints are, therefore, shock-absorbers, and are most efficient during the period of active life. They tend to become fixed by bony ankylosis when increasing age brings this period to an end. The joints of the pelvis are affected in the female by the considerations of parturition. It is well known among cow-keepers that the time of calving can be predicted by palpation of the sacro-iliac joints and the softening of their ligaments, which facilitates birth. In human beings the same process takes place during the last two months of pregnancy.

During the puerperium involution of the joints takes place, premature activity tending to produce laxity and consequent pain. As with the uterus, subinvolution is automatically cured by a further pregnancy with a more carefully-managed puerperium. In chronic cases extra-articular fixation will give a certain cure.

The stability of diarthroses depends, in such situations as the hip, partly on the cohesion of surfaces and the effect of atmospheric pressure, but in the looser joints these factors are negligible and stability depends on the specialized ligaments and, above all, on muscle-tone. The lateral ligaments are so placed that the distance between their upper and lower attachments remains constant for all positions of the joint. The importance of muscle-tone is greatest in the shoulder, where the necessity for free mobility has led to a diminution of the

actual joint surface. Its early restoration is highly important in all reconstructive operations.

Movement of a joint is produced by leverage, and for this to be effective there must be adequate muscle-power and good muscle-tone, a firm fulcrum and a not disproportionate weight. In the shoulder the fulcrum is normally unstable, and in reconstructive operations the preservation of maximum length of the humerus is of paramount importance, as the power of the deltoid decreases with the shortening of its lever. Where possible, as in the elbow or knee, removal of bone should take place mainly on the proximal side of the joint so as to avoid bony contact and preserve the levers. It is also important that the efficiency of flexors and extensors be evenly balanced, as inequality of potential leads to instability. The familiar Trendelenburg test illustrates well the principles of leverage. It is not, of course, a pathognomonic sign of dislocation; it merely indicates that the gluteal muscles are inadequate, and it can be equally well elicited in some cases of poliomyelitis or infantile coxa vara. The integrity of the lever is at fault, either through loss of a stable fulcrum or through the weakening of controlling muscles by disease, or by the approximation of their origin and insertion.

The range of movement of diarthrodial joints is never checked by bony apposition, except the temporo-maxillary by meeting of the teeth. Even in the elbow, where the ulna might be supposed to impinge on the olecranon and coronoid fossæ, soft tissue is interposed and the impact is not on the cartilage. In most cases limitation of range is controlled by ligaments, as in the thigh; by the apposition of soft parts; or by muscle tension.

TYPES OF OPERATION

Manipulation.—Restoration of function to a joint may not require open operation. The treatment of stiff and deranged joints often requires manipulation, a procedure which demands accurate diagnosis, skill and experience, lest harm rather than good result.

Manipulation is contra-indicated in the presence of inflammation or infection. The best results are obtained in cases of traumatic origin, where intra- or extra-articular adhesions limit the range of motion, or for the reduction of dislocation. Manipulation should be restricted or avoided if the subsequent reaction of the joint may cause such pain that the restored movement is useless. Certain articulations respond badly to manipulation, particularly the elbow and interphalangeal joints. If active movements can restore the range, passive movement by manipulation is best avoided.

The principle of manipulation is to put the affected joint through a full range of all its movements while the muscles are relaxed, and this is usually best achieved under anæsthesia. If the density of the adhesions is sufficient to make subsequent reaction in the joint severe, repeated manipulations gradually increasing the range of movement are preferable. It must be remembered that manipulation of a stiff

joint may endanger the bones which may be decalcified. The force applied must therefore be controlled and steady, not using the length of the bones as a lever and supporting them firmly while moving the joint.

General method.—Full anæsthesia is required for complete relaxation. Some surgeons maintain that nitrous oxide is insufficient; and this is true for the spine, hip and shoulder but, when properly administered, it suffices for other joints, as a period of relaxation always occurs and can easily be noted with experience. The pre-administration of basal anæsthetics such as avertin or nembutal is contra-indicated, as they seem to make it much more difficult to obtain muscular relaxation by subsequent inhalation anæsthesia. Injections of pentothal for manipulations have proved ideal. Adjacent bones susceptible to fracture must be protected during the operation by splints, such as two metal gutters or a piece of Gooch splinting firmly bandaged on. The various movements of the joint are performed seriatim with steadily applied force and, in most cases, to the full degree; no jerky movements are permissible. Where, however, the adhesions are very firm, the trauma of a complete mobilization may be too severe, and the operation can then be done in two or more stages.

After the operation, if few adhesions have been ruptured, massage, faradism, and exercises are employed as soon as the patient has recovered consciousness; if there has been extensive trauma, it is better to bandage the joint firmly and evenly over a thick pad of wool for twenty-four hours before further treatment is commenced. No splint is required. Pain after the operation is unusual, if the manipulation has been complete, and in any case should be of short duration, and range of movement should be maintained or increased. Prolonged pain and diminishing range are indications for rest. All active movements are encouraged, and assisted active movement of the joint should be carried out through the full range daily. The pain felt during the early days of treatment is soothed by massage, heat, and sedative electricity (anodal galvanism) Gymnastic exercises will complete the cure. For the hip and shoulder, an assistant is required to steady the pelvis and scapula respectively, and the movements of hyperextension and rotation must not be neglected. In treating the knee, flexion must be full, as it frequently happens that only at this point are adhesions ruptured, and the movements of internal and external rotation must be remembered. The temptation to mobilize obstinately stiff fingers is great, but experience teaches that, while small degrees of disability are well treated by this method, fingers whose mobility is seriously limited are intolerant of force, and require gradual methods.

Aspiration.—Aspiration of a joint may be employed for both diagnostic and therapeutic purposes.

Diagnostic.—Diagnosis of joint conditions is frequently assisted by a study of synovial fluid.

The insertion of a needle, under full aseptic precautions, will enable fluid to be withdrawn into a sterile syringe provided that the needle is within the joint cavity, the quantity of the fluid sufficient and sufficiently liquid and free from clots. An intravenous or spinal puncture needle is usually of adequate size.

If only a small quantity of fluid is present aspiration may be difficult, especially in the deeper joints. The best approach to the larger joints is as follows:

Hip.—(1) Anterior: The femoral artery having been palpated one inch below the inguinal ligament, the needle is inserted lateral to the artery and pushed directly backwards through the capsule into the cartilage of the femoral head. To prove that this is the case, the thigh should be externally rotated slightly, whereupon the hilt of the needle will move medially. Very slight withdrawal of the needle to allow the bevel to emerge from the cartilage will allow aspiration or injection of fluid into the joint. If the joint is distended with pus it will be unnecessary to insert the needle into the femoral head.

(2) Laterally: The needle is inserted above the tip of the great trochanter, pointing medially and slightly upwards, until it impinges on the femoral neck. The point of the needle is now directed more upwards so that it slides along the upper surface of the femoral neck until the capsule is penetrated.

Knee.—The needle is inserted through the expansion of the vastus lateralis one inch lateral to and on a level with the upper part of the patella, and enters the space between the lateral femoral condyle and patella.

Ankle.—The needle is inserted at the antero-lateral aspect of the ankle joint medial to the anterior part of the lateral malleolus.

Shoulder.—The acromio-clavicular joint is palpated and the needle inserted one inch in front of this, pointing backwards and slightly downwards until it reaches the head of the humerus, more to its medial side.

Elbow.—Aspiration is carried out from the lateral side, the needle being inserted between the olecranon and head of the radius immediately below the capitellum.

Therapeutic.—Distension of a joint with blood or fluid is painful and stretches the capsule and ligaments, and aspiration followed by bandaging will relieve the tension and often prevent the reaccumulation of fluid.

The removal of fluid in infected joints allows confirmation of the diagnosis and often gives a hint of the prognosis; a positive smear but sterile culture suggests a mild infection, the organisms being killed by slight bactericidal powers of the synovial fluid. Repeated aspiration is therefore of value in such infections.

In joints infected by organisms sensitive to antibiotic agents repeated aspiration followed by injection of penicillin or other antibiotic is the treatment of choice. As much fluid as possible should be

aspirated and replaced by enough liquid to reach all recesses without distending the joint capsule. This procedure should be repeated at 48-hourly intervals as long as necessary.

Arthrography.—Of recent years the injection of air or opaque fluids has been increasingly used as an aid in treating joint conditions. Although the interpretation of radiographs of such joints presents difficulties, it is a particularly useful procedure in the case of congenital dislocation of the hip and shoulder disabilities, such as supraspinatus tears.

The amount of fluid injected naturally varies with the size of joint, usually from less than 5 millilitres for an infant's hip to 8 millilitres for an adult shoulder. A satisfactory injection fluid is one third strength Pyelosil which is not irritating to the synovia and is rapidly excreted.

Arthrotomy consists in the exposure and opening of a joint, and may be either an operation in itself or the preliminary to further measures.

Erasion.—The joint is opened, diseased synovial membrane dissected away, and foci of disease in the bones curetted. This operation was formerly practised for tuberculosis, but has become almost obsolete as conservative measures produce at least equally good results. Many surgeons now perform a similar operation in chronic arthritis with beneficial results. It has been found that very free " synovectomy " is permissible, as the membrane is re-formed. These operations are therefore tending to become more and more extensive.

Excision.—In excision the whole joint is resected, without any effort to reconstruct it. For tuberculosis every stage between the simplest erasion and an extensive resection has been performed, but these operations will now be required but rarely. Each case must be judged on its merits, but some indication will be given later for the treatment of individual joints. Opinions differ on the value of primary excision for injury The emergency surgeon is concerned only with the saving of life or limb, and must provide drainage and arrest sepsis at all costs. The reconstructive surgeon, on the other hand, while deploring any unnecessary sacrifice of bone, is not justified in criticizing adversely what have often been operations of necessity.

Arthroplasty.—This is essentially an artificial pseudarthrosis. In the lower limb, where stability is of great importance, successful arthroplasty is more difficult. In the upper limb, where the range of movement is more important than stability, a wide excision often acts as a satisfactory arthroplasty.

In order to obtain permanent articular surfaces and to prevent subsequent ankylosis many substances have been interposed between the bone ends, and until the development of vitallium cups for arthroplasty of the hip by Smith-Petersen, most surgeons employed flaps of fascia.

The use of a vitallium cup in the hip joint leads to the formation of a smooth covering of fibrous tissue, both of the acetabulum and of the remodelled head of the femur. Smith-Petersen has shown that this fibrous tissue is capable of undergoing a metaplasia into fibrocartilage, and even into hyaline cartilage, and is therefore the nearest approach to restoration of a normal joint that has yet been achieved.

Apart from the perfection of technique, the ultimate result of nearly all arthroplasties depends to a great extent on the after-treatment, and this in turn greatly depends upon the will and perseverance of the patient. A long period of free movements with weight bearing eliminated is required to obtain a successful range of motion.

Arthrodesis.—This operation has for its object the abolition of movement in a joint, and may be performed by intra- or extra-articular methods or by a combination of the two. In the former case the surgeon aims at obliterating the joint cavity and substituting firm union between the joint surfaces. Where the bone-ends are relatively undamaged, nothing more is needed than the removal of cartilage and the apposition of the surfaces; but if much bone has been lost, more elaborate measures will be required. In the latter he constructs, by grafting, a bridge of bone uniting the contiguous bones around the joint. Fixation is indicated where a joint has ceased to be under muscular control, either through incurable paralysis of the muscles or extensive loss of bone, and in certain cases of arthritis where pain is intolerable and uncontrollable by other means.

Ankylosis was divided by Thomas into *unsound*, where disease is active and deformity progressive, and *sound*, where the reverse is the case. Unsound ankylosis calls for fixation. Sound ankylosis, if in bad position, calls for operation; if it is in good position, operation is only indicated if a mobile joint is necessary or desirable.

The **best position for ankylosis** is *that in which all diseased joints* should be treated, namely that which will produce the most useful limb should ankylosis result, as follows:—

Shoulder.—45°–90° abduction (the younger the patient the greater the angle, as the scapula is potentially more mobile), and 20° flexion in front of the coronal plane, the latter angle facilitating the movement of the scapula round the chest-wall.

Elbow.—The requirements of the patient must be considered. In most cases 90° will be convenient. If both elbows are ankylosed, the right should be more and the left less than a right angle, the left being required to carry food to the mouth with a fork and the right to cut up the food.

Radio-ulnar.—The forearm midway between pronation and supination.

Wrist.—Dorsiflexion to a moderate degree is essential to the preservation of an efficient grip.

Hip.—Slight abduction and external rotation. Some surgeons advise full extension, and this is certainly advisable when there is any doubt

of the permanency of the ankylosis. It must be noted, however, that when ankylosis is fixed and permanent, flexion to 30° gives a better gait and permits the patient to sit with more comfort. The consequent lordosis is amply compensated by these advantages.

Knee.—Full extension. Many surgeons advocate 185°, as rendering stairs more easy, but the same objections arise as in the hip when there is doubt of the solidity of the ankylosis.

Ankle.—Experience shows that 5° of dorsiflexion is better than a right angle, though the latter is advocated by some surgeons.

OPERATIONS IN VARIOUS CONDITIONS

Wounds of joints.—Wounds of joints may be accidental or surgical. The latter should be sterile but the former are almost invariably contaminated.

The primary surgery of joints wounds is urgent and of great importance. Direct wounds should be immediately excised with the removal of all foreign bodies and damaged tissues. If possible the synovial membrane should be closed with interrupted sutures. This closure of the joint cavity prevents further contamination from outside, allows the retention of penicillin solution and enables the joint to recover its mobility without formation of adhesions.

If the synovial membrane cannot be closed and constant supervision is possible, the skin should be sutured or a skin flap swung over the hole into the joint. Otherwise the wound may be left open under vaseline gauze and if there is no active inflammation closed by delayed primary suture on the third to fifth day.

At the time of primary surgery, sterile penicillin solution should be injected into the joint through undamaged tissues: 50,000 or 100,000 units of penicillin are dissolved in enough fluid to reach all recesses but without distending the joint.

Immobilization by plaster or other splint is required. The joint should be aspirated and more penicillin injected at intervals of 48 hours. Two or three aspirations usually suffice, but immobilization must be continued until the joint is healed, and longer if there are any signs of irritability such as pain or swelling on attempting to resume movement.

Wounds of joints complicating compound fractures present more difficulties and dangers, but the principles of treatment are the same, early and absolute immobilization being particularly important even at some cost in anatomical reduction of the fracture.

After operations on joints milder degrees of infection may be difficult to diagnose as a simple hæmarthrosis may be very painful and cause a rise in temperature to more than 100° F. Where infection is present the inflammatory process will cause tenderness of the synovial membrane away from the area of the operation. In such cases aspiration and the injection of an antibiotic to which the infecting organism is sensitive should be begun at once.

An infected joint which does not respond to aspiration and antibiotics and becomes filled with pus requires drainage by arthrotomy. Large incisions should be made which are dependent. Patients with infections of those joints which are not easily drained by posterior incisions, such as the knee and hip, are best treated in the prone position in a plaster spica. Joints which have suppurated for any length of time are best allowed to ankylose in good position, as the articular cartilage has usually been so damaged that a painless, movable but stable joint cannot be obtained. Late resection of the joint may allow movement and moderate stability.

In all cases of joint infections by sensitive organisms there must be systemic administration of appropriate antibiotics to prevent spread of the infection beyond the joint.

Operations for tuberculosis.—It has been said that there is no place for operative surgery in the treatment of active tuberculous joints, except amputation where life is endangered.

This view has already been modified and may require complete revision in the near future.

The orthodox treatment of tuberculous joints is conservative measures until the local and general condition is quiet, and then operative measures if necessary to restore the maximum function of the limb and prevent the late dangers of progressive deformity or reactivation.

The operative measures are usually arthrodesis in the lower limb and shoulder to restore stability; sometimes excision in the elbow and wrist to provide mobility.

Operation is justifiable in certain cases in which conservative treatment has failed to secure quiescence.

In hip joint disease quiescence can sometimes be accelerated by subtrochanteric osteotomy or by ischio-femoral arthrodesis. For advanced cases, Girdlestone's excision of the joint may be life saving.

In certain cases of spinal tuberculosis with paraplegia costotransversectomy or the more extensive lateral approach to the dura with decompression is called for in the presence of active disease

The surgery of pyogenic infections of joints has been transformed by penicillin and the surgery of tuberculous joints may also be changed by antibiotics. Streptomycin and *para*-aminosalicylic acid have an effect on joint tuberculosis and cause the healing of even long-standing secondarily infected sinuses if necessary with the surgical obliteration of the sinus tracks. Possibly these, or some new antibiotic, will permit earlier, safer and more conservative operations on the tuberculous joints themselves.

The normal method of healing in tuberculous joints is by a fibrous ankylosis, which may or may not allow a useful range of motion If no movement is possible, the joint may be sufficiently secure to be left alone, but where a slight amount of movement is allowed, injury, or even the ordinary stresses of use, may stretch the fibrous tissue and

lead to the formation of a secondary deformity. Unfortunately, injury may so tear the fibrous ankylosis that reactivation of the disease occurs.

Owing to these risks, many joints are best converted into bony ankyloses, which are comparatively secure against relapse and which completely prevent the development of secondary deformities. This is particularly true of the hip joint and as it is inadvisable in many cases to open a joint which has been infected by tuberculosis, extra-articular fixation is usually employed, where the anatomical arrangement allows.

Operations for chronic arthritis.—Joints which are sufficiently painful to cause disability, particularly if the range of movement is greatly diminished, often require operative treatment. Although such lesser operations as arthrotomy and synovectomy may be employed, the usual problem is whether arthroplasty or arthrodesis will result in better function of the limb.

The results of arthrodesis are more certain than those of arthroplasty at the present time. A single painful, arthritic hip is probably best treated by arthrodesis, the resulting disability due to lack of motion being acceptable. Where the condition is bilateral, however, arthrodesis of one hip is likely to lead to rapid deterioration of the other and the disability of two stiff hips is very severe indeed. In such cases arthroplasty is the procedure of choice.

OPERATIONS ON INDIVIDUAL JOINTS

Temporo-maxillary Joint

Operation on this joint is occasionally indicated in cases of inability to open the mouth, due, it may be, to dislocation of the condyle or of the interarticular fibro-cartilage, or to arthritis. In dislocation, attempts will have been made to reduce it by manipulation; these may fail, and it will then be necessary to perform an open operation for reduction. In arthritic cases, where possible, excision of the condyle is to be preferred to Esmarch's operation on the horizontal ramus, but excision may be inadvisable owing to cicatrices.

Technique.—An incision is made, 1 in. in length, either horizontally along the lower border of the zygoma on a level with the tragus, or preferably inclining upwards and forwards from that process. (Fig. 25.)

The temporal branches of the facial nerve, which run parallel with the latter incision, are drawn to either side, and the parotid gland downwards and backwards. The masseter fibres are separated from the zygoma with an elevator, the capsule exposed, and a vertical incision made into the joint. A displaced fibro-cartilage is either sutured into place or removed. The condyle, if dislocated, is either levered back into position or cut off with bone-forceps or a Gigli saw. Where there is partial or total ankylosis from arthritis, the joint is mobilized with an elevator or gouge, the external pterygoid insertion divided, and the

condyle levered out and cut off, the fibro-cartilage being left behind, if possible, and the periosteum removed with the bone. In cases of actual bony ankylosis with total destruction of the joint there may be no sign of the condyle. It is then necessary to excise enough bone to allow the easy introduction of the tip of the forefinger. If this

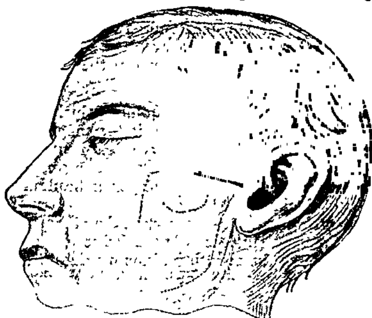


Fig. 25.—Line of incision for operation on the temporo-maxillary joint.

removal does not permit full movement, the same operation will be required on the opposite side and must be carried out at the same sitting.

After-treatment consists in early movement and, probably, forcible movement under gas on two or three occasions. Arthroplasty has little advantage over simple excision, as the residual fixity is largely due to peri-articular structures.

A transient facial palsy is not uncommon after the operation.

Sterno-clavicular Joint

Excision.—Tuberculosis of this joint, which is not uncommon, calls for early excision, owing to the difficulty of conservative treatment and the risk of extension of the disease to neck or thorax, once the limits of the joint are passed. The operation is simple, the end of the clavicle and all diseased tissue being removed.

Fixity of this joint is more disabling than is commonly recognized, the mobility of the shoulder girdle being much impaired, and excision is indicated as soon as recrudescence of sepsis is no longer to be feared. Unreduced dislocation may (rarely) call for excision when important structures are compressed by the displaced end of the clavicle.

Acromio-clavicular Joint

This joint is occasionally the seat of unreduced dislocation and arthritis, frequently of traumatic origin. Excision of the joint and wiring of the surfaces together has been performed, but the results are

not encouraging. The condition is rarely very disabling, and is best treated by palliative methods. In the reconstructive surgery of both this and the preceding joint, fascia lata sutures, passed through the bones, have proved most valuable.

The Shoulder

Approach.—Four operations are commonly used for exposing various aspects of the shoulder joint.

(1) *Anterior.*—An incision is made along the deltoid-pectoral groove from the clavicle to the tendon of pectoralis major. The line of contact of the muscles is marked by the cephalic vein which is retracted medially. If the deltoid is well developed the exposure is improved by dividing its long attachment to the clavicle, which can subsequently be resutured into position.

On separating the muscles by powerful retraction the coracoid process and its attached muscles are exposed. Two holes are drilled in the coracoid to facilitate reposition by suture and the process divided between them with an osteotome.

Reflecting the tip of the process downwards and medially exposes the front of the shoulder joint covered by the tendon of subscapularis, while laterally the tendon of the biceps lying on the anterior aspect of the humerus is hidden by the covering of the bicipital groove. The musculo-cutaneous nerve crosses the lowest part of the field, but should not be in danger.

Division of the tendon of the subcapularis exposes the shoulder joint and the anterior margin of the glenoid. The synovial membrane is thin and its division exposes the head of the humerus, a large part of which can be inspected by rotating the arm upwards and outwards.

(2) *Sabre cut exposure.*—An antero-posterior incision is made over the top of the shoulder, passing over the acromio-clavicular joint. Removal of the acromion after separating the deltoid attachment will expose the whole of the upper part of the shoulder covered by the short rotator muscles passing to their insertion in the great tuberosity. Lying on these muscles is the subdeltoid bursa.

If arthrodesis of the shoulder is intended by this exposure, the acromion is preserved.

(3) *Posterior approach.*—This exposure is much less commonly required than the others. An incision is made starting at the spine of the scapula, running downwards and outwards one inch lateral and parallel to the posterior margin of the deltoid. The margin of the muscle is defined and its attachment to the spine of the scapula divided.

The muscle is then turned outwards until the circumflex nerve is seen entering its deep surface running from the quadrilateral space. The lower and posterior part of the capsule of the joint is exposed by retracting teres minor upwards or this muscle may be temporarily separated from its insertion. The long head of triceps arising immediately below the glenoid is a guide to the joint.

In closing the wound the deltoid must be resutured to its origin.

(4) *A limited exposure* of the shoulder joint may be obtained by a vertical incision from the tip of the acromion on the antero-lateral aspect of the shoulder. The incision in the deltoid should be in the direction of its fibres, preferably along one of the fibrous intersections. The incision in the deltoid must not exceed $1\frac{1}{4}$ inches in length from the acromion for fear of cutting the circumflex nerve.

Deep to the deltoid the subacromial bursa may be opened and explored. If the floor of the bursa is incised the greater tuberosity of the humerus and the conjoined tendons of supraspinatus, infraspinatus and teres minor can be observed by externally rotating and internally rotating the humerus.

Incision of the conjoined tendon in the length of its fibres will expose the outer part of the humeral head.

This incision is chiefly used for exploration of the bursa, removal of calcium deposits in the tendons or suture of peripheral tears of the tendons, but a larger exposure of this area is obtained by the sabre cut approach and removal of the acromion.

Excision. Indications.—(1) *Tuberculosis*, where conservative treatment is unsuccessful.

(2) *Destructive infective arthritis and epiphysitis*, where simple drainage is unsuccessful.

(3) *Gunshot and other compound fractures and dislocations* with extensive destruction. The objects are the removal of loose pieces of bone and drainage.

(4) Some cases of old-standing *irreducible dislocation*. Open operation should be undertaken for dislocation (*a*) where there is a co-existing fracture of the humerus, the dislocation being reduced and the fracture then treated by ordinary methods, (*b*) where previous attempts at reduction have failed, or an interval of six weeks has elapsed since the injury. The anterior incision is used and, where possible, the head is replaced, a very determined effort being made to accomplish this before performing excision. Tough adhesions and thickened capsule may need division, and the muscles attached to the tuberosities may obstruct reduction. In the latter case the tuberosities should be chiselled off with their attached muscles, and replaced and pegged in position after reduction has been effected. If reduction be impossible, excision or arthroplasty is indicated.

After-treatment.—The limb is put up either on an abduction splint or, preferably, in plaster in the position of ankylosis. To apply the plaster is not easy, but when properly done it is far the best method, and on the correctness of the application most of the results of the operation depend. The chest and arm are enveloped in flannel or wool, and felt pads are bandaged in position, over the iliac crest and the root of the neck on the affected side, and under the opposite axilla. (Fig. 26.) Three or four plaster bandages then cover in the arm and thorax, reaching well down to the hip. Next, three plaster

bandages are unrolled and made into strips 18 in. in length; these are applied over the hip, across the shoulder, and around the axilla from chest to arm. More bandages are applied until the cast is sufficiently thick. A thin strip of metal is bent and applied so as to pass from mid-forearm along the arm to the axilla, down the chest to [illegible]

so as to free the abdomen, a width of only 5 in. (in adults) being left under the opposite axilla. (Fig. 27.) Windows are cut over the wound or wounds. If drainage has been employed the drain is removed in forty-eight hours. If a splint has been used it should be replaced by

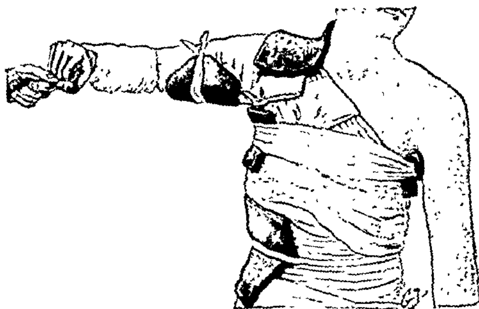


Fig. 26.—Application of plaster to shoulder in abduction.

First stage, showing wool covering and felt pads in position.

plaster in ten days; if plaster, a new plaster will usually be required at this time, as that applied at the time of operation will have become stained and odoriferous.

If ankylosis is desired, immobilization must be maintained for three months, the upper part of the plaster over the arm and forearm (Fig. 27A) being removed after three weeks for the purpose of faradism and massage to the muscles. If movement is desired, the plaster is removed from the shoulder in addition after three weeks (Fig. 27B), the appliance being kept in place by the substitution of a strip of padded webbing over the shoulder. From this time onwards faradism is applied to the deltoid, and the patient encouraged to lift the arm from the splint, aided at first by the masseuse. When he can do this with ease and strength, it is well to remove the plaster and sling a large soft pillow between arm and chest while treatment is continued, a smaller pillow being used as the range of abduction power increases.

Arthrodesis. Indications.—Flail shoulder or irremediable deltoid paralysis, where the muscles controlling the scapula are good and the rest of the limb gives promise of useful function, the nature of the task before the surgeon depending on the presence or otherwise of the head of the humerus. The inevitable loss of rotation at the shoulder should be remembered, as some patients may feel that this outweighs the advantages of fixation.

(*a*) In infantile paralysis the head is present, and no more is needed than the removal of the opposing cartilaginous surfaces and of synovial membrane. It is often well to "mushroom" the end of the humerus in order to increase the area of bony contact. The anterior incision may be used, but a deltoid flap is quite permissible, the long tendon

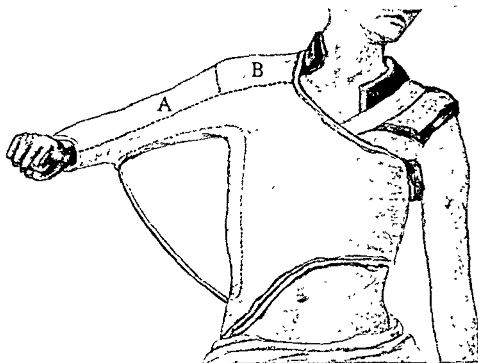


Fig. 27.—Application of plaster to shoulder in abduction.

Second stage, showing completed plaster with metal arm-support. The dotted lines on the arm indicate situations in which plaster should be subsequently cut away. The padded webbing on the opposite shoulder is also shown.

of the biceps being carefully preserved. The after-treatment is as for excision when movement is not desired. This operation should not be done on children under ten, as the head of the humerus is not sufficiently bony until that age is reached.

Technique.—A sabre cut incision is made over the acromion. The deltoid, which is usually completely atrophic and paralysed, is divided. The muscles inserted into the greater and lesser tuberosities are detached and the biceps tendon lifted from its groove and preserved.

The articular cartilage of the head of the humerus is removed until cancellous bone is exposed and the glenoid similarly treated. A thin slice of bone is removed from the upper and lower surfaces of the

acromion and this process is half cut through at its neck. With lion forceps the whole process is bent downwards. With an osteotome inserted between the humeral head and great tuberosity the latter process is prised up so that, when the head is forced into the glenoid in the optimum position of abduction, the acromion can be inserted into the cleft.

A vitallium screw or nail passing through greater tuberosity, acromion and humeral head renders the whole stable. The wound is then closed and fixed in a plaster spica. The screw does not need subsequent removal.

It is important to pay attention, not only to the degree of abduction in which the arm is fixed, i.e. 70 degrees, but also the degree of rotation. In men a slight degree of internal rotation allows the hand to be in front of the eyes when working at a bench and to raise a glass to the mouth. A position of neutral rotation is said to be valuable in enabling them to reach their hair when the arm is elevated.

The difficulties of putting a plaster shoulder spica on an unconscious patient are not negligible even with a Hawley table and it is often wise to apply the trunk portion of the plaster before the operation, adding the arm portion to it at the conclusion of the procedure.

This form of arthrodesis is usually quite satisfactory in cases of tuberculosis, but if necessary a purely extra-articular operation may be performed by Brittain's method.

Recurrent Dislocation of the Shoulder

Recurrent dislocation of the shoulder is common in young adults of both sexes and in epileptics.

The first dislocation is usually the result of considerable violence, but subsequently the dislocation becomes more frequent with less violence until mere extension of the shoulder joint with external rotation will suffice to produce it.

The dislocation is usually produced by the humeral head being forced forward and inward so that the cartilaginous labrum is torn away from the anterior rim of the glenoid—Bankart's lesion. Rarely posterior dislocation occurs.

A very large number of operations have been devised as a cure for the condition, but not more than three are commonly used in this country: These are (1) Bankart's; (2) Putti-Platt's; (3) Nicola's.

Bankart's operation.—This procedure is devised as far as possible to restore the normal anatomy and therefore has some advantage over the other two, but it presumes that Bankart's lesion is present in every case.

The shoulder joint is approached by the anterior exposure already described (p. 93). The joint having been opened a probe is passed round the margin of the bony glenoid to discover the area of separation of the labrum. In long standing cases the bony margin is often flattened and eburnated. This is roughened and two or more drill

holes made from the anterior roughened area to near the margin of the articular surface. This is the technically difficult part of the operation and is facilitated by retracting the head of the humerus laterally with a special retractor and by drilling the holes which are at right angles to the line of vision by means of a dental drill.

Part of the cartilaginous labrum is now cut away and the capsule fastened to the raw bone by silkworm or other unabsorbable sutures passed through it and the drill holes.

The subscapularis is then resutured and the coracoid replaced by suturing through the drill holes made prior to its division. The platysma and skin are sutured and a shoulder spica bandage applied and the arm placed in a sling. The arm is kept at the side for three weeks and then active movements are instituted. Two months should suffice for a full return of movement.

The scar on the anterior surface of the shoulder is apt to become keloid and in young women this may be avoided by the use of X-ray irradiation when the stitches are removed on the tenth day.

Though very successful when properly performed, the technical difficulties of Bankart's operation has probably interfered with its popularity.

Putti-Platt's operation.—This operation is devised to strengthen the anterior part of the capsule of the shoulder joint and part of its success is probably due to the fact that it lessens the range of external rotation of the shoulder, the movement which is most likely to precede dislocation The loss of this range of movement is not a serious disability in most occupations and it can be performed without determining the presence of Bankart's lesion.

The joint is exposed anteriorly as before.

Technique.—The shoulder joint is approached by the standard anterior exposure, but the tendon of biceps and coraco-brachialis are divided $\frac{1}{2}$ in from their origin instead of detaching the bony process itself.

The subscapularis is divided 1 in. from its insertion after defining its upper and lower borders

The subscapularis is retracted medially and the capsule opened and the anterior margin of the glenoid examined.

The distal stump of the subscapularis is sutured [illegible] the labrum
periosteum and capsule or deep surface of the s[illegible] musc[illegible]
The sutures are tied while the arm is internally [illegible]
portion of the capsule is sutured to the surface of [illegible]
subscapularis tendon and then [illegible] part
itself is sutured to the cov[illegible]
so that the arm can be e[illegible] the [illegible]

The wound is closed as pre[illegible] d, af[illegible]
the tendons to the coracoid p[illegible]

The arm is bandaged to the [illegible]
breast for four weeks and the[illegible]

instituted. Return of free movement may take several months and manipulation may be required.

Nicola's operation.—This operation does not attempt to repair the normal anatomy of the joint, but relies on the conversion of the tendon of the long head of the biceps into a sort of ligamentum teres which holds the head of the humerus into the glenoid and prevents excessive external rotation. Unfortunately the tendon becomes worn between the articular surfaces and, not being very strong, may give way with only moderate violence, so that the condition recurs. It should, therefore, only be used, if at all, in unathletic patients.

The anterior approach is used, but the coracoid and subscapularis are not divided. The biceps tendon is exposed in its groove and divided in its lower part. The upper part of the shoulder joint is opened above the top of the bicipital groove and the tendon withdrawn upwards. A drill is now passed obliquely through the bed of the groove through 1½ in. of bone to emerge through the articular cartilage of the head about ½ in. from its anterior margin. The cartilage round the hole is smoothed off and the drill hole enlarged until the biceps tendon will lie snugly in it. The free end of the tendon is fastened to a strong suture passed through the drill hole and drawn down until it emerges in the groove where it is resutured to the distal end and to the periosteum on either side. The tension of the tendon should be such that external rotation with extension of the shoulder is slightly limited.

The wound is closed as usual. Movements of the shoulder can be begun earlier than with the two preceding operations and the disability time is a good deal shorter.

Fairbank's operation. Indication.—Neglected cases of birth paralysis with fixed internal rotation of the shoulder.

Technique.—An anterior incision is made as for excision, the joint is opened, and the subscapularis tendon and coraco-humeral ligament are divided. Occasionally the supraspinatus may need division. The wound is closed, and the arm fixed in abduction and external rotation with plaster. The period of fixation will vary according to the degree of paralysis. Care must be taken that the shoulder does not become fixed in abduction. In most cases movement and re-education should be commenced in three weeks from the operation, although the arm must be kept on a plaster splint for a further period before voluntary control is obtained.

The Elbow

Arthrotomy.—The elbow joint may be approached through lateral, posterior or medial incisions, but for most purposes the former is preferable.

An incision is made along the external supracondylar ridge and carried vertically downwards to the level of the neck of the radius. It then curves backwards and downwards parallel with the fibres of the supinator. By stripping the common extensor origin from the

humerus and dividing the orbicular ligament, the joint may be opened and a good view obtained of the capitellum and head of the radius. When the external lateral ligament is divided, the elbow joint may be opened by abducting the elbow and the major portion of the joint brought into view.

Excision. Indications.—(1) Joints severely damaged by injury can be excised and a surprisingly good range of movement at the elbow joint obtained. The usual error is to remove too little bone rather than too much, and even though the joint may appear flail at first, a considerable degree of stability returns. It is important that these joints are kept at a right angle during after-treatment.

(2) Tuberculosis of the elbow in adults responds well to excision, and although it is better to do this operation after a period of conservative treatment, it is often successful in the presence of secondary infection of the sinuses.

Technique.—Provided the operation can be carried out in less than three-quarters of an hour, a pneumatic tourniquet is used. If the operation is likely to exceed this time, the pressure must be temporarily released during the operation. If possible, the patient is placed in the fully prone position, the surgeon standing on the affected side; but if this position be contra-indicated, the arm may be drawn across the body, the surgeon then standing on the opposite side to the one affected. A vertical posterior incision is made, 4 to 5 in. in length, with its centre at the tip of the olecranon. This incision is made down to the bone throughout its extent, splitting the triceps. Partly with a sharp rugine and partly with the knife, the tissues on the outer side are peeled away from the bones until the anterior aspect of the condyle and the head and neck of the radius are exposed, great care being taken to preserve the insertion of the triceps with its lateral expansion into the deep fascia, the anconeus, and the lateral ligament of the joint.

A similar proceeding is then carried out on the inner side. The ulnar nerve is here in danger, but will probably not be seen, and can be avoided by using the knife and keeping close to the bone. The internal lateral ligament is preserved, and the separation carried forward so as to expose the front of the inner condyle and the coronoid process. Some surgeons insist upon the importance of the removal of the periosteum, owing to its tendency to form excessive new bone, but in my opinion this is not essential. In tuberculosis or acute arthritis it will strip off easily, but in other and old-standing cases the separation is difficult. At this stage the bone section may be made by protruding first the end of the humerus and then the forearm bones through the wound. A better plan is to pass a large, broad elevator across the front of the humerus, raising the anterior ligament from the bone, divide the humerus, and then push the forearm bones backwards and complete the section. The site of section will depend on the extent of the injury or disease. In most cases the humerus is divided transversely just above the condyles, and the forearm bones at the level of the neck

of the radius. (Fig. 28.) The sawn sections should be made transversely cylindrical in order to check forward displacement of the forearm. This can be accomplished either by using a Butcher's saw or by shaping the sawn sections with a gouge. A gap of 1½ to 2 in. should be left when the arm is extended. If the operation be performed for tuberculosis, all diseased tissue is dissected away and isolated foci are curetted from the bones.

After-treatment.—The joint is fixed at a right angle in a dorsal plaster slab, extending from the upper arm to the heads of the metacarpals. A complete plaster is not advisable, owing to the possible swelling of the limb.

After two weeks the stitches are removed and the patient encouraged to move the joint. Only a small range of movement should be attempted at first, as a greater range might involve some danger of re-opening the operation wound. This assisted active movement is continued daily henceforward, the joint being advisedly fixed

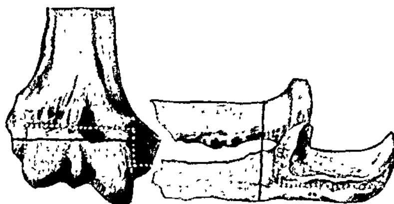


Fig. 28.—Lines of section of bones of elbow joint.

The continuous lines show those usually required in excision of the elbow joint. The dotted lines show those employed in arthroplasty, it being understood that the head of the radius has been removed at a previous operation.

alternately in flexion and extension in the intervals of treatment. At the end of three weeks the hand may be slung to the neck and lowered daily, no other splint being required. The elbow should be kept flexed at night until electrical treatment and re-education have restored the power of flexion. In many cases of excision, although flexion and extension are well controlled, there is marked lateral instability. With time, as the muscles strengthen, this will largely disappear, but where much bone has been removed a certain amount will persist unavoidably. In these cases an elbow-cage is required. A plaster cast of the arm is prepared, care being taken to mould the plaster well over any remaining bony prominence in the condylar region. On this cast a moulded leather appliance is made, encasing the arm and forearm, and provided with lateral steels fixed to the leather and jointed at the elbow.

Flail elbow.—Frequently, especially when little attention has been paid to the preservation of the triceps attachment and the arm has

been treated in full extension, either the elbow becomes completely flail, or, if some control remains, during flexion the forearm bones must be carried up in front of the humerus before a fulcrum is obtained Such a joint, even when controlled by an appliance, is of little use. Two courses are open. Where possible, the action of the triceps must be restored, in order to balance the joint. Simple re-attachment of the muscle to the stump of the ulna will suffice in some cases, but where much of this bone has been lost, the fixation of a bone-graft into the ulna in addition, in order to form a new olecranon, is well worthy of trial. This method must necessarily fail where the bone-ends are narrow, as no fulcrum can be obtained by the forearm being drawn up to the side of the pointed humerus. An attempt may be made to produce ankylosis (1) by spreading the end of the humerus into a mushroom shape with a chisel, leaving the chips attached, freshening the ends and upper surfaces of the forearm bones, and fixing the surfaces together with kangaroo tendon passed through drill-holes in the bones; or (2) by employing the freshened end of the humerus, if it is pointed, or inserting an intramedullary graft from the tibia if the humerus is broad, and passing this through large holes drilled in radius and ulna, the upper ends of which are previously freshened. The forearm is thus fixed in the mid-position and the bones are kept in apposition by kangaroo tendon passed through drill-holes. Prolonged fixation in a plaster including the chest will be necessary.

Alternatively, the construction of a mobile joint may be attempted (1) by removing scar tissue and binding the bones together with fascia lata (Platt), (2) by an arthroplasty planned to engage the pointed end of the humerus between the bevelled forearm bones (McMurray); or (3) by splitting the lower end of the humerus longitudinally and wedging the two portions apart with a small piece of bone cut off from the pointed end. In this V-shaped socket the forearm bones are engaged and fixed with kangaroo tendon, the triceps tendon being re-attached as above (Aitken).

In these cases the *after-treatment* is that of arthroplasty.

If these methods fail, the permanent wearing of a support fixing the elbow and including the shoulder is the only alternative.

These results are described to emphasize the extreme importance of removing the minimum of bone when operation is performed for an acute condition, and of correct after-treatment in all cases of excision.

Arthroplasty. Indications.—A decision whether an elbow should be left ankylosed in good position or an attempt made to give a mobile joint can only be reached after considering the occupation of the patient. Manual labourers are generally better off with a fixed elbow, as at present it is impossible to promise stability of the joint, especially in a lateral direction. The condition of the muscles controlling the joint, the degree of scarring in the neighbourhood, the function of the other joints of the limb and of the opposite elbow must also be taken into consideration Certain cases are better treated by excision than

by arthroplasty, which is much more difficult and should be reserved for cases where the bones are relatively undamaged, or there is only a small degree of painful movement.

Technique.—The site of incision will be governed by the position of any scars, but, when possible, a straight posterior incision is preferred. Various methods have been used, but it will suffice to describe that advocated by Elmslie (" After-treatment of Wounds and Injuries "), which has been found very successful. The patient lies in the fully prone position, and no tourniquet is used. An 8-in. posterior incision is made with its centre at the tip of the olecranon. Little more than skin is reflected on either side, and a flap of deep fascia and aponeurosis, 4 in. long, is dissected up from over the posterior forearm muscles with its pedicle attached behind the inner condyle of the humerus. The triceps tendon is defined, split into superficial and deep halves, and divided in a Z-shaped manner, the deep half being divided close to the olecranon. The bones are cleared as in excision. The joint is either broken open, if only partially ankylosed, or divided with a curved osteotome, if fixed. The humerus is made to protrude, and a portion of the end is removed, the line of section being quadrilateral, leaving the two condyles, and crossing just distal to the olecranon fossa. (Fig. 28.) This latter and also the front of the bone are well cleared, and the section made transversely cylindrical. (In case of difficulty, a less elaborate division, as for excision, will suffice.) The articular surface of the ulna is freely cut away, only half the thickness of the olecranon and the root of the coronoid process being left. The cut ends of the bones are smoothed with a file, if necessary. The fascial flap is sutured over the end of the humerus, the triceps re-united, and the wound closed. If there is ankylosis of the superior radio-ulnar joint, this is better treated by excision of the head of the radius at a previous operation. The elbow is fixed at right angles and treated on the general lines of arthroplasty.

Albee,* realizing that stability of the joint depends largely on a balance of power between biceps and triceps and that this is impaired by the shortening of the olecranon, devised an operation, similar in general plan, in which the olecranon is retained, and detached with a tapered portion of the ulna, the insertion of the triceps remaining intact After remodelling of the joint this portion is re-attached so as to lengthen the olecranon on the sliding graft principle. He employs fascia lata from the thigh in preference to a local graft.

Experience has shown that when, as often occurs, movement of the elbow is limited by a bony block, attempts to remove this by operation are rarely successful and may lead to actual diminution of movement. If operation be considered advisable, nothing short of a full arthroplasty should be attempted in the majority of cases.

Arthrodesis.—It is exceedingly difficult to obtain bony union between the humerus and bones of the forearm, and the simple removal of

* *J Bone Jt Surg*, Oct 1933, xv, 979

cartilage is inadequate. The bones must be bound together either by kangaroo-tendon sutures passed through drill holes or, preferably, by a tibial bone-graft driven through a hole in the olecranon up into the medulla of the humerus. *At least three months' fixation in* plaster is needed. In poliomyelitis with paralysis of the flexor muscles it may suffice to excise a lozenge-shaped piece of skin and subcutaneous tissue from the front of the elbow and suture the wound transversely, after the method of Sir Robert Jones.

Superior Radio-ulnar Joint

Excision. Indications.—(1) Ankylosis of the joint, especially when the elbow-joint also is ankylosed. (2) Unreduced dislocation of head of radius. (3) Some cases of fracture of the head of the radius.

Where the head of the radius is shattered, or the fragments so displaced as to interfere with its subsequent function, the head of the radius should be removed. This is more satisfactory than removing *single separated fragments. The decision as to excision should be* made within 48 hours of the fracture. Delay beyond this period is likely to result in permanent limitation of movement of the elbow and the risk is increased with every additional day's delay. If late excision is necessary, it should be delayed for six months, when the danger of new bone formation will have greatly lessened.

The head of the radius should not be removed in children, or in greenstick fractures of the neck, as in such cases a gross radial deviation of the hand may subsequently develop.

Technique.—An incision 2 in. in length is made downwards from the external condyle over the head of the bone. The glistening fascia over the extensor muscles will then be seen. This is divided in the length of its fibres and the orbicular ligament divided so that the head of the radius is exposed The head of the bone is then removed with mallet and chisel and after ensuring that free movement without grating is obtained, and that all loose fragments have been removed, the orbicular ligament and fascia are sutured with catgut.

After-treatment.—*The elbow may be splinted by means of a* plaster slab for a few days, during which time movements of the fingers are actively encouraged. After the wound is healed, active movements of the elbow may be started, rotation usually preceding flexion and extension. At no time should massage or passive movements be allowed and the active movements should only be within the limit of pain. Restoration of the full range can often be obtained within six weeks.

Inferior Radio-ulnar Joint

Arthroplasty of this joint has been replaced by **Gallie's operation.** It is a matter of common experience that fractures of the lower quarter of the ulna have a strong tendency to non-union. Profiting by this, Gallie advised treating ankylosis of this joint by the simple procedure of excising an inch of the lower quarter of the ulnar shaft *with the*

periosteum. Excellent results are obtained, the bone readily acting up to its reputation for non-union, and movement taking place freely at the pseudarthrosis thus produced.

THE WRIST

Excision.—Systematic excision of the wrist for tuberculosis is not often required as the condition is rare. Provided the disease is quiescent, satisfactory function can be maintained by other means.

Partial excision.—Un-united fractures of the carpal scaphoid invariably lead to arthritic changes in the wrist within a year. If they are not present union may be obtainable by prolonged fixation in plaster, but this is always tedious and may be unsuccessful when the fracture has existed for more than six months.

Provided the fragments are not grossly displaced, union may be obtained by means of a bone graft as devised by Armstrong. This consists of the insertion of a peg graft from the non-articular tuberosity of the scaphoid in the long axis of the bone. The bone is first drilled, with radiographic observation, and great care is required to obtain correct alignment. The graft is then driven down through the drilled hole and after closing the wound the wrist must be immobilized in a scaphoid plaster for a minimum of three months.

In cases of un-united fractures of the scaphoid, where arthritic changes are present, either arthrodesis of the wrist or excision of the whole proximal row of carpal bones is required, provided that the disability is sufficient to justify surgery. In heavy manual workers where strength and stability are particularly required, arthrodesis is the operation of choice.

Dislocation of the lunate can be reduced by manipulation in early cases. After two weeks' delay open operation may be required. The wrist joint is opened from the dorsum and the cavity formerly occupied by the bone is cleared of debris. By manipulation of the hand and leverage the bone is brought back into its normal relationship.

In long-standing cases of dislocation, particularly where the median nerve has been involved, excision of the bone is the operation of choice. This is best done from the palmar surface.

Arthrodesis of the wrist.—The wrist joint should be arthrodesed in a position of slight dorsiflexion which allows the full strength of the grip to be maintained. Three methods of arthrodesis are employed, according to the individual indications or the preference of the surgeon.

The wrist joint may be opened from the dorsum and dislocated. With a chisel the carpus is split in the coronal plane. The lower end of the radius is formed into a wedge in the same plane and the carpus impaled upon it.

In most cases the lower end of the ulna will require removal to obtain a satisfactory position and to allow rotation of the hand.

Arthrodesis of the wrist can also be carried out by means of a tibial graft extending from the base of the third metacarpal to the radius,

with a groove cut across the dorsum of the carpal bones to receive the graft. When the wrist is slightly dorsiflexed the upper end of the graft is impacted into the medulla of the radius and held under an over-hanging ledge in the base of the metacarpal. Unless the joints between the individual carpal bones are deprived of their articular cartilage at the same time, this method of arthrodesis is not suitable for un-united fractures of the scaphoid, as movement between the fragments is not abolished.

The third method is to use a triangular plate of bone taken from the dorsum ilii, which is fixed into a correspondingly shaped raw area, which has been formed on the back of the carpus and lower end of the radius, by chiselling away the dorsal surfaces of the bones By this means most of the carpal bones and bases of the metacarpals can be securely fixed to the radius.

Metacarpus and Phalanges

Owing to the greater elaboration of their sheaths, the flexor tendons are far less tolerant of surgical disturbance than the extensor tendons. Consequently, operations on the joints of the hand should be performed from the dorsal aspect, where possible. These operations will mainly consist of open reduction of dislocations, and arthroplasties. When operating on a dislocation of long standing it will be impossible to decide beforehand whether the dislocation should be reduced or an arthroplasty performed. Arthroplasty is indicated when either (*a*) reduction is impossible, or (*b*) the cartilaginous surfaces of the joint are so damaged as to render firm fibrous ankylosis probable. The mobility of the transverse metacarpal arch, a matter of great importance in the maintenance of an effective grasp, depends on the integrity of the intermetacarpal and carpo-metacarpal joints. Where these are ankylosed, a series of arthroplasties may be performed through a dorsal incision. Ankylosis or unreduced dislocation of the trapezio-metacarpal joint is approached through an incision between the tendons of the extensores longus et brevis pollicis, and similar conditions of the metacarpo-phalangeal joint through an incision on the radial side of the long extensor. The metacarpo-phalangeal joints of the fingers may be similarly treated, bone being removed, in arthroplasty, at the expense of the phalanx in order to prevent the knuckle falling back out of line with its fellows. In these arthroplasties the metacarpal end should be completely cleared from the surrounding soft parts. A strip of fascia lata is removed from the outer aspect of the thigh, folded in half, and sewn up into a bag with fine catgut. This bag is then slipped over the bone-end and easily remains in place.

After these operations, extension should be applied to the digit for two weeks before movement is allowed. It is best effected by applying a plaster cast to the wrist and palm, previously encased in wool or felt, and incorporating in the plaster a stiff wire loop stretching beyond the extended fingers and bent into a notch opposite the affected finger.

A tape is attached to the finger with adhesive plaster, and tied over the notch.

Sacro-iliac Joint

Tuberculosis of this joint is a disease chiefly of adolescent and adult life, and if it does not readily yield to conservative means may be treated on the same radical lines as in other joints. A semilunar skinflap is

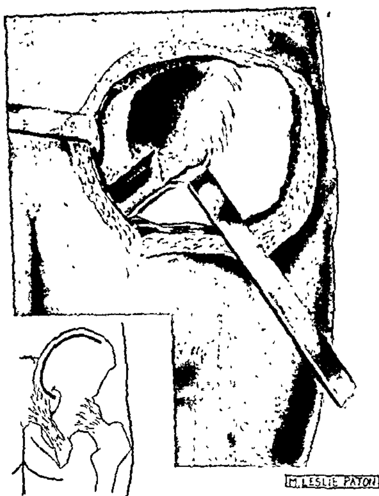


Fig. 29.—Smith-Petersen's operation. Inset, skin incision.

turned forwards from over the joint, the glutei separated from th bone and an opening made into the joint with hammer and chisel, al diseased bone being removed and abscesses evacuated.

Arthrodesis is performed by the method of Smith-Petersen. A incision is made along the posterior two-thirds of the *iliac crest* curving round the posterior superior iliac spine and running forwar parallel to the gluteus maximus for 2 or 3 in. If the sacro-iliac join be projected on to the outer aspect of the cleared ilium, the inferic edge will correspond with the sacro-sciatic notch and the anterior wit the middle gluteal line. (Fig. 29.)

With a motor-saw and osteotomes a rectangular block of bone is cu out from the ilium, opening the joint; the cartilage and disease

material are curetted away and a socket of corresponding size cut in the sacral surface. After removal of cartilage, the block is countersunk into this socket, crossing the joint. Additional fixation may be obtained by osteotomy of the edges of the slot.

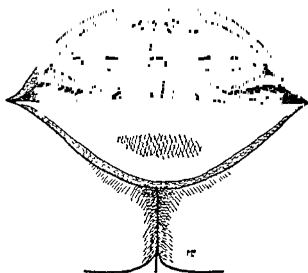


Fig. 30.—Author's operation for sacro-iliac fixation (trans-sacral graft).

Of extra-articular methods, that which I have devised* has proved of value and has the advantage of extreme ease. A semi-lunar skin-flap, turned down, exposes both posterior superior iliac spines and the muscles between them. Both spines are cleared and the intervening spinous process removed from the sacrum, leaving a raw area. Tunnels of $\frac{3}{8}$ to $\frac{1}{2}$-in. diameter are made in the two spines and a tibial bone-graft of suitable size driven across, passing through both tunnels, under the muscles, and with its raw surface in contact with the raw area on the sacrum. (Fig. 30.) No extra fixation is required and the two sacro-iliac joints are held together as by a tie-beam.

Considering the extreme gravity of sacro-iliac tuberculosis, one or other of these methods is indicated. They are often suitably employed in such milder conditions as painful arthritis or intractable instability of the joint. Post-operative fixation, first by plaster and later by a pelvic brace, will be indicated, the duration naturally varying according to the severity of the disease.

Hip Joint

Although a large variety of operations are performed on the hip and a still larger number have been devised, the approach to the joint is usually obtained by one of three routes.

(1) Smith-Petersen or antero-lateral approach.—This is an extension of the old anterior approach to the joint and is a modification of that described in Kocher's textbook.

A vertical incision is made from the anterior superior spine of the ilium over the space between sartorius and tensor fasciæ femoris for 4–5 in. From the upper end the incision is carried backwards immediately below and parallel to the iliac crest to its highest point.

Anteriorly the fascia is divided and deep to the space between the muscles the rectus femoris is exposed. In the upper half of the incision the origins of tensor fasciæ and the gluteus group are divided below the iliac crest and all the muscles stripped downwards from the dorsum

* *J. Bone Jt Surg.*, July, 1926, viii, 491.

ilii, exposing the reflected head of the rectus and the antero-lateral part of the capsule of the hip joint. For the purpose of arthroplasty, Smith-Petersen widens the approach by detaching the origin of sartorius and Poupart's ligament from the anterior superior spine, the abdominal muscles from the anterior third of the iliac crest and the anterior part of the iliacus from its attachment to the ilium. By an osteotomy of the anterior inferior spine he reflects the rectus laterally, so that the anterior and inferior parts of the acetabular rim are exposed.

It is important to expose and preserve the branches of the femoral nerve crossing the lateral border of the iliacus to supply the rectus, and at the lowest part of the standard incision the nerves to vastus lateralis accompany the lateral circumflex artery across the uppermost part of the femoral shaft.



Fig. 31.—Anatomy of posterior approach to hip joint. Inset, skin incision.

(2) Lateral or goblet incision (Murphy).—A U-shaped incision with its lowest part at the base of the great trochanter is made, if necessary with an extension down the lateral aspect of the femoral shaft (the stem of the goblet).

Anteriorly the ilio-tibial band is divided and the upper portion with the gluteus maximus turned upwards. By dividing the base of the greater trochanter obliquely upwards with an osteotome this process, together with the insertions of gluteus medius and minimus, is turned upwards, giving a good exposure of the whole lateral aspect of the capsule of the *hip joint*.

(3) Posterior approach.—This is a much more severe operation than the others and should be reserved for cases requiring a very extensive exposure of the joint, and possibly dislocation, with the inevitable shock caused thereby. However, it is a valuable method and in the rare cases where drainage is required, the position of the wound will naturally be favourable. The patient lies on the sound side and the

surgeon faces the back. An incision is made from the posterior edge of the tip of the great trochanter downwards along the femur for 3 in., and upwards for 4 in. towards the posterior superior iliac spine. (Fig. 31.) If arthroplasty be intended the skin is well dissected back on each side and a large fat-and-fascia flap raised from the subjacent gluteus maximus.

The gluteus maximus is then split in the line of its fibres, and its attachment to the femur peeled off for a short distance and partially divided. Many vessels are cut at this stage, and should be tied off before the operation is continued. Two courses are now open. If but a limited exposure of the joint be required, the interval is found between the glutei medius and minimus on the one side and the pyriformis on the other, and the former two muscles are stripped from the great trochanter forwards until the anterior intertrochanteric line is reached. The other muscles inserted into the trochanter are divided. The digital fossa is the site of an arterial anastomosis, and considerable bleeding may be encountered here. It is advisable to ligature vessels during the progress of the operation, as an accumulation of forceps hampers the view. To separate the muscles from the bone effectively, it is necessary to rotate the limb inwards and outwards as occasion requires. With a fixed hip this cannot be done, and the operation becomes unnecessarily difficult. Where there is any difficulty of this kind, it is easier, and gives a better exposure, to divide the great trochanter. An aneurysm-needle is passed round its base in order to define the extent, and the base divided with a broad osteotome. The bony process can then be retracted upwards with the muscles attached.

The capsule is incised (in arthroplasty, excised) and the gluteal origins are stripped away from around the acetabulum with an elevator. By these means the superior, posterior, and most of the anterior surfaces of the head and neck of the femur are exposed. One of three procedures may now be adopted—excision, arthroplasty, or arthrodesis.

1. Excision. *Indications.*—(1) Extensive destruction of the joint by injury. (2) Some cases of pathological dislocation. Where stability of the limb is already ensured by the fixation of the displaced head by fibrous tissue, etc., malalignment of the limb will be better corrected by osteotomy. (3) Rarely, tuberculosis.

Technique.—The neck of the femur is either divided *in situ* with a keyhole saw or an osteotome, the surrounding parts being protected with Lane's elevators, or is sawn through after the joint has been dislocated by rotation of the limb. The site of section will depend on the limits of the disease, no more bone being cut away than is consistent with the removal of disease and provision for drainage.

2. Arthroplasty of the hip.—This operation is indicated where a movable stable hip joint is required, as in bilateral arthritis or ankylosis, or where a rigid lumbar spine contra-indicates arthrodesis.

Three methods will be described, the vitallium cup arthroplasty of Smith-Petersen with its modification by Judet, pseudarthrosis with osteotomy of Batchelor, and Whitman's operation.

Vitallium cup arthroplasty.—The hip joint is approached by the modified Smith-Petersen route already described. The anterior lip and any osteophytic rim of acetabulum is removed and the hip joint is dislocated by external rotation and adduction of the limb.

If ankylosis is present, curved osteotomes are used to separate the femoral head from the acetabulum.

The head of the femur is rendered hemispherical with chisel and reamer and the acetabulum is hollowed out by the same methods. The acetabulum should be enlarged and deepened as far as the pelvic cortex. All bone dust and fragments must be washed away with saline solution and the acetabular margin cauterized with diathermy to prevent new bone formation.

A vitallium cup of the right size must be fitted with care so that it fits with the required degree of firmness on the femoral head and in the acetabulum. This requires repeated trial until the head moves in the cup on flexion and the cup moves in the acetabulum on abduction and the joint is stable. The wound is closed and the limb slung in a Thomas splint in slight traction.

After three weeks motion is commenced and gradually increased, chiefly by the efforts of the patient. Later, non-weight-bearing walking on crutches is permitted. Full weight-bearing is not allowed for as long as six months.

The operation is a severe one and blood transfusion should be available. Hospitalization and after treatment are long and success depends largely on the patient's efforts. The results are very much better in cases of osteoarthritis than in ankylosing spondylitis.

Judet arthroplasty.—A recent development of this type of operation is the use of an artificial femoral head made of plastic material and surmounted on a spike which is driven into the divided part of the femoral neck after the natural head has been removed.

Batchelor's operation.—This procedure is carried out in two stages.

(1) The hip is exposed by the Smith-Petersen approach and the head and neck of the femur are removed. The neck of the femur must be removed to its base. The wound is closed and the limb slung on a Thomas splint with slight traction for a few weeks until the wound is soundly healed and the patient in good condition.

(2) A low Schanz type of osteotomy of the femur is performed through an 8 in. incision over the lateral aspect of the upper femoral shaft. If possible a beak on the outer cortex of the lower fragment is impacted into the medulla of the upper, to promote stability. The lower fragment is then abducted 40 degrees on the upper, and is fixed in that position by a stainless steel plate, previously bent to the

required angle. The plate is fixed by at least six screws which penetrate both cortices of the bone.

The wound is then closed in layers and the limb again slung on a Thomas splint with little abduction.

Movements are started early and weight-bearing is allowed as soon as the osteotomy is firmly united.

When the limbs are parallel the upper fragment of the femur is inclined at such an angle as to support that side of the pelvis. A surprisingly good degree of movement and stability are obtained at the cost of some shortening. The latter is, of course, of little consequence if bilateral operation is performed.

This operation is considerably less severe than Smith-Petersen's, so that it is available to old or weak patients and the after-treatment is not so long or arduous.

Whitman's operation.—By an antero-lateral or posterior approach the trochanter and femoral neck are exposed. The former is divided at its base and displaced upwards with the muscles attached. In cases of arthritis the hip is now dislocated, warning having been previously given to the anæsthetist, in order that the inevitable shock may be countered. The head of the femur is removed and the stump of the neck rounded off and placed in the acetabulum. With the thigh in abduction, the trochanter is re-attached by a peg, wire or nail to a rawed area lower down on the femur. The leverage power of the glutei is thus preserved. The after-treatment is that of arthroplasty.

Although it is not strictly an operation on the joints, reference may be made to the operation of **bifurcation (Lorenz)** in the treatment of painful arthritic hips.* Here a transverse inter-trochanteric osteotomy is performed, and the lower portion is pushed inwards towards the acetabulum. Union occurs, and weight-bearing is in part transferred to the pelvis with relief of pain.

3. Arthrodesis of the hip.—Fixation of the hip may be required for the relief of pain, prevention of progressing deformity, to secure stability and, in tuberculosis to obtain healing by bony ankylosis and security against relapse or deformity by permanent immobilization.

Fixation of the hip joint in good position does not produce a very serious disability, provided the lumbar spine is mobile and the other hip maintains a normal range of motion. If these factors are absent arthrodesis is usually contra-indicated.

The hip may be arthrodesed by intra-articular or extra-articular methods. The latter are almost always applicable, the former should not be used in cases of tuberculosis or recent sepsis.

Intra-articular arthrodesis.—This operation is usually performed on adults suffering from painful osteoarthritis of the hip. It is contra-indicated if there are any signs of arthritis in the opposite joint.

Many patients with this condition are old and infirm and consequently

* McMurray, *Brit J Surg*, 1934-35, No 88, xxii, 716.

the severity of the operation and the necessary post-operative immobilization must be taken into consideration.

Method 1.—The hip joint is exposed by the Smith-Petersen approach. The capsule is divided near its attachment to the acetabular rim. The bony rim may be chiselled away if there is much osteophytic lipping. The joint is dislocated by forced external rotation and adduction. The manœuvre should be performed with care to avoid a fracture of the femoral neck. The articular cartilage is removed from the femoral head and acetabulum and the raw bony surfaces shaped in such a way that there is good bone to bone contact when the dislocation is reduced. When the wound has been closed a double plaster spica is applied with the hip in optimum position for ankylosis. The plaster spica must be retained for from four to six months. The plaster must include the foot on the side of operation to control rotation, and the knee should be flexed a few degrees.

Static quadriceps exercises should be started early and after six to eight weeks the posterior half of the plaster below the knee may be bivalved to allow flexion of the knee under supervision. Stiffness of the knee is a frequent sequel of this prolonged immobilization unless precautions are taken.

This method has several disadvantages:

(*a*) The operation, which involves dislocation of the hip, is severe and an intravenous supply of saline solution or blood should be available.

(*b*) Old patients do not tolerate prolonged immobilization in plaster well. The danger of hypostatic pneumonia must be combated by breathing exercises and turning the patient frequently.

(*c*) Even a well fitting plaster may not adequately immobilize the hip of a fat patient.

(*d*) It involves heavy nursing and prolonged hospitalization.

(*e*) Bony ankylosis may not occur.

Assistance in obtaining absolute fixation of the bones and relief from the prolonged plaster fixation may be had by the use of a long trifin nail (12 or 12·5 cms.). This is passed, under radiographic control, obliquely upwards from below the great trochanter along the neck of the femur across the joint into the thick bar of ilium which passes up from the roof of the acetabulum towards the sacro-iliac joint.

The pin may be inserted at the time of the major operation or subsequently. If well placed and not subjected to stress the nail will maintain complete fixation for a few months and will accelerate fusion.

Method 2. (*Wiles.*) Fig. 32.—The hip is first fixed by means of the long nail as described above, and then the outer aspect of the hip joint is exposed and the cortical bone removed from the upper surface of the head and neck of the femur. A graft, 3 in. by 1½ in., is cut from the outer table of the ilium immediately above the acetabulum and slid downwards across the joint on to the raw surface of the neck. It is then fastened to the ilium and femur by two vitallium screws.

The accessible portion of the joint is chiselled out and packed with cancellous chips from the ilium.

By this method plaster fixation may be dispensed with, as the graft fixes the joint well and ankylosis is rapid. The patient may be allowed up on *crutches in six weeks and full weight bearing allowed at three* months.

This method can only be used where there is no gross deformity of the joint and when no change of position of the limb is required. It is, however, much less severe and avoids most of the disadvantages of the first method.

Extra-articular arthrodesis.—This type of operation is usually employed following the conservative treatment of tuberculosis of the hip to prevent deformity and as an insurance against reactivation of the disease. As a rule the disease *should be quiescent after the* cessation of all bone destruction.

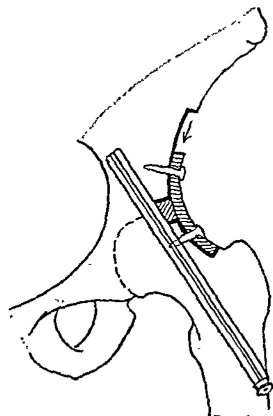


Fig. 32.—Wiles' method of arthrodesis.
(From Wiles, Essentials of Orthopædics, Churchill.)

It may, however, be employed in other conditions in preference to intra-articular methods.

Method 1. (Ilio-femoral arthrodesis.) Fig. 33.—The ilium may be fused with the femur by means of iliac, trochanteric or tibial grafts Iliac grafts are highly osteogenic and can be obtained without enlarging the hip incision.

This operation can be used for children, though preferably not under the age of 10 years. It is usually employed when tuberculous arthritis has reached quiescence, when the disease has not spread far up *into the ilium and when the* position of the limb does not require alteration. In those cases with deformity a subsequent subtrochanteric osteotomy will be required

The method described is that advocated by Seddon

Blood transfusion may be helpful but is seldom required.

Six to eight weeks of ambulatory treatment improve the patient's vasomotor control, an important factor in preventing shock in children who have suffered prolonged recumbency A double plaster hip spica is then applied. The plaster includes the foot on the affected side, but ends above the knee on the sound side The plaster is carried

well up on the trunk and reinforced at the groin and gluteal margins. A window is cut about 8 in. by 6 in. over the field of operation.

The application of the plaster a few days previous to operation saves twenty minutes of anæsthesia and accustoms the patient to the plaster.

At operation the patient is placed in the half lateral position. Wool is tucked between skin and plaster and a gauze surround pasted to



Fig. 33.—Ilio-femoral arthrodesis.
(*From Burns and Ellis, Recent Advances in Orthopædics, Churchill*)

the skin and plaster edge with Mastisol. The plaster is covered with sterile towels in the usual way and wound towels are employed as soon as the skin incision has been made.

The Smith-Petersen approach is used and the upper part of the great trochanter exposed.

A full thickness rectangular graft is cut from the dorsum ilii with a chisel, the graft being usually about 2 in. by $\frac{3}{4}$ in. A portion of the outer table of the ilium above the acetabulum is raised from below upwards and a deep notch cut in the great trochanter, and the graft is wedged between the two.

The muscles are then sutured in place and the skin wound closed. Bulky dressing covered by thin plaster over the window give sufficient pressure to prevent hæmatoma formation.

Fusion should be sound in three months, when weight bearing is allowed with protection from a short single spica until X-ray evidence of good consolidation is present.

Method 2. (*Ischio-femoral arthrodesis* (*Brittain*)).—This method involves the use of massive tibial bone graft which is passed through a subtrochanteric osteotomy into a slot cut in the ischium. It has the advantages of:—

(1) The graft is in compression as against tension in the ilio-femoral arthrodesis.

(2) The position of the limb can be altered without a second operation.

(3) The hip joint is freed from strain.

X-ray control is required. A 5 in. tibial graft of the whole width *of the tibia, including the anterior and medial borders, is cut with a* motor saw. The line of osteotomy of the femur is determined radiographically.

If a Michel clip is placed at the junction of the middle and lower third of a line joining the anterior superior spine to the symphysis pubis, it will usually be projected on the X-ray over the upper part of the obturator foramen below the acetabulum. This is the point at which the osteotome should be aimed.

A 4 in. incision over the lateral aspect of the upper end of the femur is made and the bone exposed in the subtrochanteric region. A blunt instrument, such as a ring-handled spike, may be passed in front and behind the bone and pushed inwards until the ischium is felt. Radiograph examination with these *in situ* will demonstrate the line of osteotomy and will, incidentally, ease the mind of the operator that the sciatic nerve and femoral vessels are held away from the osteotome.

A broad graduated osteotome is used to make a clean subtrochanteric osteotomy, sloping slightly upwards with the end at right angles to the long axis of the body. The osteotome should be held horizontal to the ground, or at any rate not pointing at all downwards.

The osteotomy of the femur being completed, the osteotome is passed onwards about $1\frac{1}{2}$ in. until the ischium is felt, into which it is driven for one inch.

Another radiograph is taken to check the position, and if satisfactory traction is exerted on the limb and a second similar osteotome is inserted above and parallel to the first for the required distance as shown by the radiograph. The first osteotome is then withdrawn and

the graft substituted for it with its cancellous surface downwards. It is driven into the ischium as the osteotome is removed. The leg is then abducted and the upper end of the lower fragment of femur displaced medially as far as possible.

The wound is closed in layers and a complete plaster spica is applied. Brittain's twin osteotomes with screw separator facilitate the introduction of the graft.

By this method correction of moderate deformity can be obtained at the time of operation. The limb should not be too much abducted and operations on cases with marked flexion deformity require extra care.

Consolidation of the osteotomy and graft are rapid. The operation

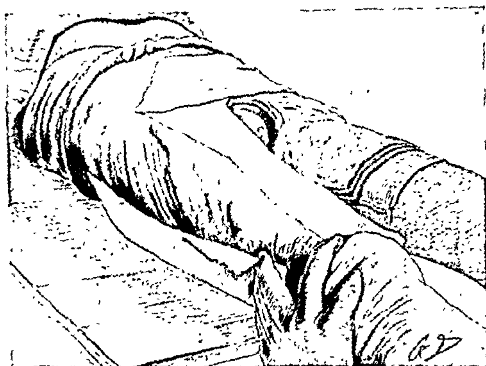


Fig. 34.—Plaster spica to hip.

First stage, showing wool covering and plaster-strengthening strips in position. The latter should not be applied until the whole has been covered by a layer of plaster bandage.

is frequently followed by bony ankylosis across the hip joint, especially in tuberculosis. It is advisable not to perform this operation before the age of 10 years.

After-treatment of hip-joint operations.—In all cases the limb should be put up in the position of ankylosis. In arthrodesis this is best effected by the immediate application of a plaster spica reaching from thorax to toes, as obviously no extension is required. (Figs. 34, 35.) The progress of ankylosis can be gauged by skiagrams, but usually at least three months will be necessary to secure a sound union. The application of plaster will enable the patient to leave bed and move about on crutches at the end of a fortnight if necessary, an obvious advantage in dealing with a patient of advanced years.

Where possible, hip-joint operations should be performed on a Hawley table. This table allows extension to the limb during the operation, if necessary, and greatly facilitates the application of plaster. If this table be not available, a pelvic rest is placed beneath the sacrum and the limb supported by an assistant.

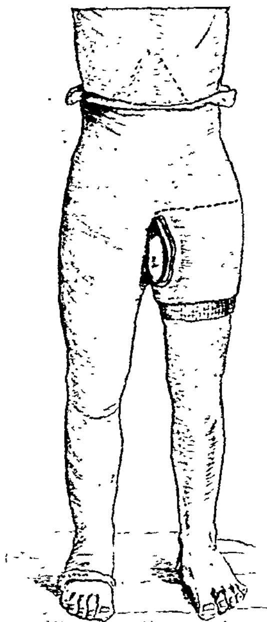


Fig. 35.—Plaster spica to hip (complete).
The dotted line indicates line of removal of a portion of the plaster at a later stage (*see text*).

The initial *post-operative plaster* should always be carried down to the toes, as otherwise considerable trouble may ensue from swelling of the distal parts. Later, the ankle and knee may be freed by cutting away the plaster. Upwards, the plaster should reach just above the lower edge of the thorax, and on the opposite side the anterior superior iliac spine must be included. In order to ensure fixation, it is a good plan to include the upper 6 in. of the opposite thigh during the first three weeks after the operation. In applying the plaster cast, pieces of felt are bandaged over the lower ribs, the whole surface is well padded with wool and covered in with a few plaster bandages. Experience teaches that the parts of a spica most likely to break are at the inner and outer ends of the fold of the groin; two thick plaster strips are therefore applied, vertically along the outer side of the hip, and from the inner side of the thigh upwards over the pubes to the opposite iliac spine. More bandages are then applied until the cast is sufficiently thick. The plaster must be well moulded over the anterior superior spines and round the knee.

In other cases, where no drainage has been employed and dressings do not need changing frequently, the limb is put on a Thomas's bed-splint with a large ring, and moderate extension applied. The splint is suspended from a Balkan frame placed diagonally to the bed, so as

to keep the limb in abduction. In cases of arthroplasty and Whitman's operation it is useful to apply an extension to the leg, and a plaster spica, from ribs to ankle, over this. From 5-10 lb. extension is then applied. After 10 days the plaster is bivalved, and movements are encouraged, and after 8 to 12 weeks the patient is allowed to put some weight on the leg, with or without the support of a caliper-splint according to the stability of the joint. Crutches will be used until full confidence is regained.

After Whitman's operation, fixation in plaster is maintained only until it is thought that firm bony union of the re-attached trochanter has taken place. After this, daily assisted active movements of the joint are instituted, a useful method, at this stage, being to sling the limb from a Balkan frame and allow the patient to control movement by a pulley.

Where repeated access to the wound is required, as in infective cases, a Thomas's abduction frame is indicated. By some surgeons this apparatus is employed as a routine for all cases, but for those unfamiliar with its use it is a difficult appliance on which to make a patient comfortable, although the perineal band around the opposite groin is very useful in preventing accommodative tilting of the pelvis.

The Knee

The majority of operations on the knee joint are for internal derangements. In the case of cartilage injuries a long incision does not increase the exposure, and as such incisions in the synovial membrane are commonly held to lead to subsequent effusions, they should be no longer than 2 in.

To expose the major part of the joint from the front a medial parapatellar incision is used. Starting 2 in. above the patella over the junction of the rectus and vastus medialis, it is carried down parallel to the medial border of the patella and patellar ligament. In the upper part of the incision some muscle fibres may be divided, but below the incision passes through tendon ½ in. medial to the patella. The synovial membrane is opened and, if necessary, the patella can be dislocated over the lateral condyle. The synovial membrane and capsule should be sutured separately on closing.

For cartilage injuries, *antero-medial and antero-lateral incisions* are required and, less commonly, a postero-medial exposure.

The anterior incisions are made with the knee flexed to a right angle over the end of the table, with the towelled foot of the patient between the surgeon's knees. The operation should always be carried out under an Esmarch's tourniquet and a good light is essential.

There are two methods of making the incision for the antero-medial exposure, either downwards and outwards or downwards and inwards from the prominence of the femoral condyle to just below the upper border of the tibia at an angle of 45 degrees. The former avoids damage to the infrapatellar branch of the long saphenous nerve and is

in the line of the capsular fibres; the latter gives a somewhat better exposure of the peripheral attachment of the meniscus.

Removal of medial meniscus.—Tears of the meniscus are not always visible on exposure from the front of the joint. Therefore, diagnosis must be made before operation and the whole meniscus removed.

The joint having been opened by the antero-medial approach, the anterior horn of the meniscus is identified and separated from its attachment to the tibia and transverse ligament. It is then grasped with strong toothed forceps and an assistant retracts the capsule on the medial side of the knee, so that the coronary ligament can be seen and divided along the periphery of the cartilage. After the attachment to the medial collateral ligament has been divided, the cartilage can be pulled laterally and displaced into the intercondylar notch, so that the posterior horn is visible and can be detached.

A stout but narrow bladed scalpel is adequate, but a number of special cartilage knives have been devised for this operation.

Even if there is a bucket handle tear and much of the meniscus is already lying in the intercondylar space, the periphery should be removed as secondary tears are not uncommon and it is easier to remove the greater part of the posterior horn.

Complete, and especially transverse, tears through the posterior half of the meniscus cannot be removed from the front of the joint. In such cases, after the removal of the anterior half of the cartilage, the joint should be closed and a postero-medial incision made 2 in. in length, vertical and behind the medial ligament.

With the knee flexed to a right angle the hamstring tendons will be found running almost horizontally in the lowest part of the wound. On dividing the synovial membrane over the joint line, the rounded posterior part of the femoral condyle will be brought into view and below it the posterior part of the meniscus, which can then be freed from its peripheral and posterior attachments The wound is then closed in layers.

This incision may also be used for the removal of loose bodies in this part of the joint.

Removal of the lateral meniscus.—This operation is performed from the antero-lateral approach and involves the division of the anterior part of the ilio-tibial band near its insertion, which must be carefully sutured subsequently. The exposure of the joint is not so good, owing to the larger synovial fat pad. The lateral meniscus is separated and removed in the same manner as the medial

It is seldom necessary to expose the posterior aspect of the lateral part of the knee joint, and in such cases it is important to avoid injuring the tendon of the popliteus which grooves the outer border of the meniscus behind its mid point.

Suture of the anterior capsule of the knee joint is facilitated by extension of the knee.

After the wound has been closed a firm pressure bandage over a thick layer of wool is applied before the tourniquet is removed. This helps to prevent a subsequent hæmarthrosis and also forms a sort of splint, limiting motion of the knee. Some surgeons prefer to apply a circular plaster for two or three weeks.

In all cases quadriceps exercises, at first static, should be carried out regularly and frequently. It is preferable that these should be learnt and practised by the patient before operation.

Erasion for tuberculosis is rarely indicated, such cases as could be treated by this measure being curable by conservative methods. It is obvious that if radical operation be performed, every stage between erasion and a full excision will be met. The advocates of erasion mention as suitable for this operation exactly those cases which are curable by other means, and insist on a subsequent period of fixation which would usually be adequate to effect cure without operation.

Arthrodesis.—The difference between this operation and that of excision (*see* below) is merely one of degree, as in no case should any unnecessary bone be sacrificed.

Excision. Indications.—(1) Tuberculosis. Extensive removal of bone in children is strongly contra-indicated as interfering with the growth of the limb. It still remains a justifiable operation in adult cases which do not yield readily to conservative means and yet are not sufficiently severe to justify amputation. With modern artificial limbs, there should be no hesitation in amputation where there are excessive destruction and sinus-formation.

(2) Disorganization of the joint by old infective arthritis or osteoarthritis, especially if there is much pain.

(3) Certain compound comminuted injuries (e.g. gunshot). Modern treatment has much reduced the necessity for this operation, and in any case the removal of bone will be strictly limited to the removal of loose fragments and the provision of drainage.

(4) Flail joints due to paralysis, the object being to lessen the amount of apparatus necessary. This is especially applicable to hospital cases.

(5) Unsound ankylosis with tendency to flexion deformity and triple displacement.

No excision or arthrodesis should be performed on a knee which is flexed more than a few degrees, as too much bone must then be removed. In active disease the knee must first be straightened by extension, and in cases of ankylosis simple osteotomy along the joint line, followed by extension, is indicated. It is dangerous to correct fully at one sitting a knee that has been flexed for a considerable period, and no advantage is gained, as gradual extension will suffice.

If it be impossible to keep the patient in bed during correction, a succession of plaster casts applied at intervals of ten days will achieve the desired result.

Technique.—A tourniquet is applied to the thigh, and the knee

flexed over the end of the table, if possible. A great number of different incisions have been employed, and access to the joint has been obtained above, below, and through the middle of the patella. The one now most generally accepted is U-shaped, commencing above one femoral condyle, descending vertically, crossing the front of the tibia at the tubercle, and ascending to the opposite condyle. This flap is dissected upwards, the skin only being raised as far as the upper border of the patella. The ligamentum patellæ and lateral parts of the capsule are divided in the same line as the original incision, and the whole flap raised, including the patella. In tuberculous cases the suprapatellar pouch is dissected away, the intra-articular structures are removed, and all side-tracks of disease opened up and cleaned. A few touches of the knife will then free the lower end of the femur on its lateral and posterior surfaces. By pushing the tibia backwards the femur is made to project, and the bone section begun. In tuberculosis one-third to two-thirds of the condyles should be removed; in arthrodesis in children the cartilage only is cut away; in adults one-third of the condyle is removed, the resultant shortening being an advantage, owing to the easier clearance of the foot from the ground in walking with a stiff knee. The femur is divided with a Butcher's saw at right angles to the axis of the shaft. The tibia is then brought forward, and a thin slice removed from its upper surface, just sufficient to expose cancellous tissue. Free access to the back of the joint is now obtained, and diseased tissue can be removed by dissection. The bones are fitted together, the alignment of the limb tested, and any errors corrected by removal of bone. After all diseased tissue has been excised, the patella may be either removed or left. If possible, Tubby's plan of removing the cartilage from the patella and baring the corresponding areas of the anterior surfaces of femur and tibia, and pegging the three together, should be adopted; this method is certainly of value in ens two excision pins driven in t ie tibial tuberosities into the o ensure approximation. If the bones fit well, this is usually unnecessary. Should there be reason to anticipate difficulty in obtaining bony union between the cut surfaces, or should this have failed, the insertion of a graft crossing the joint ensures ankylosis. This graft should be cut from the front of the tibia on the affected side immediately below the line of section of the bones and fitted into a groove in the femur. It will be found to fit better if its direction be reversed The deep tissues are closed with catgut and the skin sutured. A generous dressing is applied, and bandaged very smoothly and carefully, and the tourniquet removed. The limb is enclosed in plaster from foot to pelvis, a portion being cut round (but not removed) over the site of the incision, as the plaster is setting. This "lid" is kept in place by a bandage and can be lifted to inspect the wound.

After-treatment.—The wound is disturbed as little as possible, morphia being given to allay pain. On the tenth day the "lid" is

removed, the dressings are cut through, the stitches removed, the wound redressed, and the "lid" replaced. After three weeks a new plaster is applied under an anaesthetic, but this need not include the pelvis. A closer fit will be obtainable as less dressing is needed. The patient can then get up on crutches, but no weight must be borne on the limb. In tuberculous cases, where more frequent attention may be needed, the limb may be put on a metal splint with an interruption at the knee. An excellent method also is to encase thigh and leg in plaster, apply a Thomas's splint to the limb, and fix the splint to the leg with additional bandages, enclosing the splint. (Fig. 36.) This method effectively prevents separation of the bony surfaces.

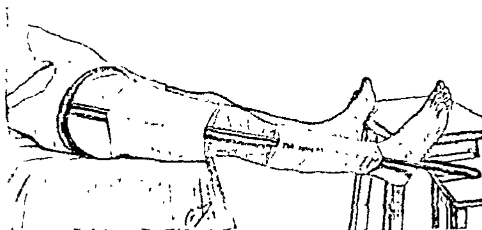


Fig 36.—Method of employing a Thomas's splint and plaster for fixation after excision of knee.

Immobilization is obtained without preventing free access to the affected area.

Arthroplasty of the knee.—It would obviously be desirable in many cases to transform a stiff or painful knee into a mobile and painless joint but unless stability can be obtained fixation is often more useful in such an important weight-bearing articulation.

Arthroplasty of the knee has not been performed frequently in this country owing to the difficulty of obtaining painless movement with stability and because it undoubtedly requires great perseverance and even stoicism on the part of the patient to obtain a good result.

Large successful series have been reported by Samson and by Speed and Trout. The latter state that arthroplasty is contra-indicated in rheumatoid arthritis, tuberculosis, osteomyelitis, obesity and osteoporosis Arthroplasty of the knee should be confined to adults under fifty years of age and the best results can be expected in patients who have had acute infective arthritis.

The best technique appears to be that devised by Willis Campbell. A vertical curved incision convex medially is made in front of the knee medial to the extensor apparatus from 4 in. above the knee to the lower end of the tibial tubercle. The quadriceps tendon is separated from the vastus internus muscle The patella is separated from the femur with a chisel and the extensor apparatus retracted laterally. The

chisel is now used to divide the ankylosis between femur and tibia completely, taking care to avoid the structures behind the knee. The knee is then flexed and the femoral condyle removed, particularly posteriorly, leaving a single curved condylar surface.

As little of the upper surface of the tibia is removed as will leave healthy cancellous bone with a slight antero-posterior concavity to fit the femoral surface forming a simple hinge joint. There must be no varus or valgus angle at the knee.

The medial and lateral ligaments must be preserved to maintain stability.

The posterior part of the patella is removed All osseous surfaces are smoothed and all loose particles of bone removed. A flap of fatty synovial membrane is separated from the tibia behind the patellar ligament, dissected and turned upwards and sutured over the raw surface of the patella. A sheet of deep fascia 4–5 in. wide and 9 in. long is removed from the outer side of the normal thigh.

The sheet is sutured at the junction of its middle and lower third to the posterior recess of the joint. The upper two-thirds covers the raw surface of the femur, the remainder that of the tibia with its smooth surfaces touching over the weight bearing area. The margins of the fascial sheet are sutured in position with catgut and the wound closed.

Moderate traction is applied on a hinged Thomas splint, but full extension is maintained until the wound is healed.

Active and passive movements are started at ten days. It should take two months to achieve 40 degrees of movement. A walking brace with hinge is required for several months.*

Recurrent dislocation of the patella.—A satisfactory operation for this condition employs a combination of several of the methods mentioned above

With the limb exsanguinated by an Esmarch's tourniquet as high on the thigh as possible, an incision is made on the anterior surface of the thigh from a point 2 in. above the apex of the patella running distally ½ in. from and parallel to the medial border of the patella and then 1 in. to the medial side of the tibial tubercle and curving outwards to end over the subcutaneous border of the tibia 2 in. below the tubercle.

The skin is freed and reflected to the outer side exposing the patella, patellar ligament and tibial tubercle, the quadriceps tendon and its expansion on either side of the patella.

The lateral expansion is incised ½ in. from and parallel to the lateral border of the patella, but the underlying synovial membrane is left intact.

With hammer and chisel the patella ligament and its bony insertion are elevated from its bed, leaving it attached by a strip of periosteum at its lower end. An area of bone 1 in. medial to the tubercle is rawed and the patellar ligament swung inwards so there is raw bone to bone contact.

* Samson, J. E., *J Bone Joint Surg*, 1949, xxxiB, 50
Speed, J S, Trout, P C, *J Bone Joint Surg*, 1949, xxxiB, 61
Campbell, W. C., Operative Orthopaedics, 1939, London (H Kimpton), pp 369 373

The tibial tubercle is fixed in its new position by a bone peg or buried vitallium screw and sutures.

This realignment of the patella will cause the incision in the lateral expansion to widen, but there will be lax capsule on the medial side of the knee. A strip of this expansion ½ in. wide and 3 in. long is made leaving it attached at its upper end only. The free end is passed laterally through the deeper part of the quadriceps tendon back superficially and sutured to the expansion of the medial vastus so as to draw the quadriceps tendon somewhat to the medial side of the thigh. The gap in the capsule on the medial side of the patella is now sutured and the skin closed. At no time should the joint cavity be opened.

After the dressings have been applied and the tourniquet removed a padded plaster cylinder is made to enclose the limb from groin to malleoli with the knee extended. Gentle static quadriceps exercises may be started at once but no great strain allowed on the tibial tubercle for several weeks and motion of the knee at a month. The time required fully to restore the muscles and knee movement after this operation may be as much as six months.

The Ankle Joint

Injuries of the ankle joint are common and the consequences of these injuries often require operation.

The common sprained ankle which is produced by forced inversion with some plantar flexion does not usually lead to instability of the joint but if the lateral ligament is torn from its attachment to the lower end of the fibula the talus is able to rock in its mortice.

This instability is usually only temporary, external splinting or even the spasm of surrounding muscles holding the position for the two to three weeks necessary for healing of the ligament. The abolition of spasm and pain by local anæsthetic injection may allow a repetition of the injury and prevent healing of the ligament. More commonly in childhood the ligament is torn off with a small portion of the still cartilaginous tip of the malleolus. This, being avascular, does not heal and permanent instability of the joint occurs.

Instability of the ankle joint can be demonstrated by an antero-posterior skiagram of the ankle while the foot is held in forced inversion and plantar flexion when the talus will be found to rotate 20 degrees or even 30 degrees in its mortice.

This instability can be cured by the fashioning of a new external lateral ligament and such an operation is well justified in the presence of material disability. The tendon of peroneus brevis is usually employed in the manner described by Watson-Jones, or some modification of it.

A vertical incision is made behind the lower third of the shaft of the fibula and carried forwards and downwards 1½ in. beyond the tip of the lateral malleolus. The skin is retracted forwards and the lateral malleolus and capsule of the joint in front of it exposed. The tendon of peroneus brevis is divided from the muscle belly and freed to within

½ in. of the tip of the malleolus. The muscle is sutured to the peroneus longus to preserve as much power of eversion as possible.

A horizontal ¼ in. hole is drilled from back to front of the malleolus emerging at the point of attachment of the anterior fasiculus of the external lateral ligament, and the free end of the tendon is passed through it.

The tendon must now be attached anteriorly either by passage through a vertical hole drilled through the neck of the talus into the sinus tarsi, or more simply by passing it round the strong ligament which passes between the under surface of the neck of the talus and the antero-lateral nonarticular upper surface of the os calcis.

Another hole is drilled in the external malleolus from near its tip anteriorly upwards and backwards to emerge near the entrance of the first hole. The tendon is passed backwards through this hole, pulled tight and sutured to itself.

The wound is closed and the foot immobilized in a below-knee plaster for six weeks. The plaster is changed at two weeks and the stitches removed. A heel is applied to the new plaster and walking allowed. That portion of the tendon which lies between its insertion and the first hole in the tibia must not be too tight or inversion of the foot will be permanently limited. Stability is restored and the operation is a uniformly successful one.

Arthrodesis of the ankle.—Fractures round the ankle joint, particularly *those involving the weight-bearing surface of the tibia*, especially after imperfect reduction, are often followed by a painful traumatic arthritis of the joint. Less commonly other affections of the joint lead to a painful arthritis.

Bony ankylosis of the ankle joint results in freedom from pain and if it occurs in a satisfactory position causes a surprisingly small disability. In women who wear higher heels fixation in slight equinus is preferable; in men the ankle should be fixed with the foot at right angles to the leg.

Two methods of arthrodesis will be described, one by an anterior approach, the other from the outer side which will be found preferable when malposition of the talus has first to be corrected.

(1) A vertical 5 in. incision is made along the tendon to tibialis anticus. The sheath of the tendon is opened, the vessels and nerves retracted outwards and *the lower 3 in. of the tibia and the front of the* ankle joint exposed. The capsule is removed and the foot plantar flexed. With a chisel the cartilage on all three faces of the talus is excised.

The cartilage is now removed from the corresponding surfaces of the tibia and fibula. A graft is cut from the anterior surface of the tibia about 2½ in. long, slightly narrower at its upper than its lower end.

A socket is cut in the upper surface of the talus so that the narrower end of the graft will fit tightly into it The bed from which the graft has been taken is deepened and its sides slightly bevelled, the bone chips so obtained being preserved. The graft is reversed and its narrow

end forced into the socket in the talus. Bringing the foot up until nearly at a right angle forces the graft back into its groove, where it should countersink and fix accurately.

The bone chips are packed into the crevices between the raw bone surfaces at the sides of the joint and the wound is then closed and a padded plaster applied.

Three weeks later an unpadded plaster is applied and weight bearing allowed. Plaster fixation is required for twelve weeks, or until skiagrams show consolidation.

(2) A 5 in. vertical incision is made behind the external malleolus. The lower part of the shaft of the fibula is exposed and the peroneal tendons mobilized from their sheath. An osteotome is placed on the fibula 1 in. above the level of the ankle joint and the fibula divided obliquely downwards and inwards.

The fibula fragment is freed from all its attachments except at the tip and turned downwards exposing the lateral side of the ankle joint. The talus can be partially dislocated outwards and its cartilaginous surfaces chiselled off. The corresponding surfaces on the tibia and fibula are also denuded. If the talus is misplaced it should now be mobilized to lie in its normal position under the tibia and care taken that the raw bone surfaces are in contact. In some cases it may be wise to make a small incision in front of the ankle and through this to remove the cartilage on the lateral surface of the medial malleolus and medial surface of the talus. A small amount of bone is removed from the lateral part of the tibia so that when the fibular fragment is replaced the whole joint fits securely. The fibular fragment is screwed to the tibia and talus by two vitallium screws. After-treatment is again by plaster for twelve weeks.

Arthrotomy for drainage is best performed by incisions in front of the two malleoli, a drainage-tube being drawn across between the two incisions, behind the extensor tendons. Where drainage of the posterior part of the joint is required, an incision is made behind the peroneal tendons, and a counter-incision made on the inner side by cutting down on forceps passed through the joint. In compound fracture involving the ankle, the site of incision will be determined by the injury, sufficient bone being removed to ensure drainage, and the foot immobilized in the position of ankylosis.

$\frac{1}{4}$ in. of the tip of the malleolus. The muscle is sutured to th

CHAPTER IV

OPERATIONS ON TENDONS, MUSCLES AND FASCIÆ

By H. JACKSON BURROWS

SURGICAL ANATOMY

THE tendons consist of longitudinally arranged bundles of fibrous tissue, the separate fibres being only very loosely bound together, so that when a tendon is torn or cut they separate easily and the end of the tendon is apt to become frayed. The longitudinal arrangement of the fibres gives a very poor hold for sutures, and consequently special methods of suturing have to be adopted. At the proximal, muscular end the strands of fibrous tissue continue either into fibrous septa in the muscle or sometimes into a flat fibrous layer upon its surface. The muscle fibres are inserted in these fibrous layers or septa. At the distal end the tendon passes into, and becomes continuous with, the periosteum of the bone. A torn tendon may pull away from the muscle fibres; it may rupture at its narrowest point; or it may be torn away from its insertion into the bone, usually carrying a flake of bone with it. The particular injury depends on anatomical circumstances and upon the way in which the force acts The tendo Achillis usually ruptures at its narrowest part, about $1\frac{1}{2}$ inches above its insertion. The quadriceps tendon ruptures just above its attachment to the patella. The extensor expansion on the back of the fingers may separate from its insertion into the last phalanx or may pull away with it a small fragment of the phalanx. The flexor tendons of the fingers have been known to tear right out of the muscle.

A tendon usually lies in a smooth sheath which is reflected over it, so that it is suspended by a meso-tendon. This may be complete; for example the tendo Achillis has an anterior meso-tendon right down to its insertion. Or the meso-tendon may be incomplete, as in the flexor tendons of the fingers, considerable lengths of which lie perfectly free. The blood supply of a tendon is derived from longitudinally-disposed vessels that enter it from the muscle; an accessory supply may enter through the meso-tendon.

In all operations on tendons it is important to avoid unr
injury to the sheath and meso-tendon and to suture the
it has been divided, if this is possible without undue t
tensions run in a direct line from the muscle
example the tendo Achillis Others pass arou

and alter their direction; they lie, covered by a part of the tendon sheath, in a bony groove bridged by a strong external fibrous layer. An example is the passage of the peroneal tendons round the lateral (external) malleolus. Other tendons, particularly those on the flexor aspects of the limbs, alter the direction of pull at the level of joints by passing beneath strong fibrous ligaments which prevent their jumping out of their grooves. In front of the wrist the flexor retinaculum (anterior annular ligament) thus forms a bridge beneath which the flexor tendons to the fingers are enclosed; in the same way there is a fibrous bridge opposite the metacarpophalangeal and the interphalangeal joints of all the fingers. These fibrous bridges over a bony groove should be respected if possible; if they must be divided they should be repaired by suture, because any permanent damage means serious interference with the function of the tendon. Adhesion of a tendon to its sheath interferes with the action of the tendon as much as complete division. In those tendons that are not enclosed in bony or fibrous canals adhesion will very often gradually stretch and free themselves, but in tendons that have to pass through such canals, for instance the finger flexors, or have to work under a fibrous bridge, adhesion is usually permanent and very serious.

TENOTOMY AND TENDON LENGTHENING

Tenotomy is surgical division of a tendon, but the name is commonly used also when the divided structure is composed of fleshy muscle fibres as well as tendon. For instance, division of the tendinous sternal head of the sterno-mastoid muscle, or of the mainly fleshy clavicular head, is indiscriminately called tenotomy; and, in tenotomy of the adductors in the thigh, the adductor longus is alone tendinous, the rest being fleshy. Myotomy, the division of the fleshy part only of a muscle, is sometimes called tenotomy, and is carried out in the same way.

When a tendon is divided inside its sheath the proximal end retracts, because of contraction of the muscle. The space left fills with blood, which within a few days is invaded by fibroblasts, so that the clot is gradually replaced by fibrous tissue. As this organizes, it contracts to an extent governed by the position in which the part is held. For example, if the foot is held in plantar flexion during healing of a divided tendo Achillis, its ends are approximated, the gap is small, and the fibrous tissue may contract so much that there is no eventual lengthening. If, on the other hand, the foot is left free, the gap may be large, the fibrous tissue has little chance of contracting, and the tendon is permanently lengthened.

Experiments show that about six weeks are required to enable the new fibrous tissue that heals a cut tendon to become strong enough to withstand tension and to undergo its fullest contraction. At the end of this time the strands of fibrous tissue have assumed a generally longitudinal direction like that in the original tendon. A tendon is very apt to adhere to its sheath at the point of division; consequently injury to the tendon sheath should be avoided as far as possible, and

the tendon should be divided where adhesion will matter least. Two or more tendons running in parallel sheaths, e.g. the peroneus longus and peroneus brevis, should be divided at different levels to prevent adhesion between them.

The best form of tenotomy knife is that shown in Fig. 37A, known as Jones's; the blunt-pointed tenotome formerly used has now been universally discarded.

There are two distinct methods of tenotomy: the subcutaneous, in which the operation is carried out beneath the skin through little more than a puncture; and the open method, in which the tendon is divided under vision.

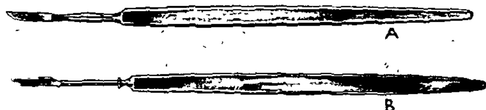


Fig. 37.—Tenotomes.

The subcutaneous method.—The original paramount advantage of this method was the rarity with which it led to infection, a risk which nowadays is almost negligible with either procedure except in an incontinent patient. The principal advantages of subcutaneous tenotomy at the present time are the minimal disturbance and scarring, and the early rehabilitation that it allows. The disadvantage is that in certain situations there is a danger of dividing important structures besides the tendon, and even perhaps of failing to divide the tendon completely. Sometimes an open operation is necessary in any event, with the object of dividing other contracted structures or for controlled tendon lengthening with suture.

In patients paraplegic in flexion—from advanced disseminated sclerosis, for instance—tenotomies of adductors and hamstrings may greatly facilitate nursing. The subcutaneous method is then wholly indicated for these reasons: it is unlikely to be followed by sepsis; it is a minor procedure; damage to such structures as the lateral popliteal (common peroneal) nerve is of little or no consequence; and there is no question of an extensive correction that would require division of other contracted structures

Technique of subcutaneous tenotomy.—The whole operation is carried out with a short-bladed, pointed tenotome, like those shown in Fig. 37. With repeated sharpening the blade becomes dangerously narrow and fragile, and the instrument should then be discarded.

The part is so held as to place the tendon slightly on the stretch, and from a point at one edge of it the tenotome is passed on the flat behind the tendon, which is then put fully on the stretch. The tenotome is

then rotated in its long axis so that the blade lies at a right-angle to the tendon with the cutting edge against it. The tendon is divided with a sawing movement, the tenotome passing from the deep surface towards the skin. As soon as the last strand has been divided, the tenotome is turned back to its initial position and withdrawn.

Some tendons are divided by suddenly tightening them across the stationary upturned blade—for instance, toe extensors by flexing the toes.

In a few cases in which there are no important underlying structures it is convenient to pass the tenotome between the tendon or muscle to be divided and the skin, and to cut inwards instead of towards the surface.

The open method.—The principal disadvantage of this method is the greater extent of the operation and the inferior cosmetic result. The advantage is the free exposure of the tissues so that it is possible to make certain of fully dividing certain structures while avoiding others. Often it is necessarily adopted in order to allow operation upon other structures besides the tendon, or as part of a tendon lengthening operation.

Method of performing open tenotomy.—The skin incision is determined by cosmetic considerations, the proposed site of division and the necessity for dividing any other contracted structures. The tendon sheath is opened, and a director is passed beneath the tendon, which can then be divided on to the instrument.

Tendon lengthening.—Because tenotomy is followed by retraction of the severed end of the tendon attached to the muscle belly, and because this retraction cannot be accurately controlled, there is a risk in certain instances that the gap in the tendon will not heal or will do so with so much elongation that the muscle is unduly weakened. Either mishap may be avoided by performing a tendon lengthening instead of a simple tenotomy.

The principle of the operation is shown in Fig. 40, p. 189.

An operation known as " sliding tenotomy " described on p. 187 is really a subcutaneous method of tendon lengthening, but the necessary omission of sutures makes it less reliable than the open operation to which the term tendon lengthening is usually confined.

After-treatment.—After most of these operations the limb needs fixation, either on a splint or in plaster of Paris, in the position that keeps the tendon stretched just to the required extent, and this position must be maintained for six weeks.

Special Tenotomies and Myotomies

Tenotomy of the sterno-mastoid muscle.—Tenotomy is carried out for the correction of " congenital " sterno-mastoid torticollis, which usually comes under observation between the ages of five and seven years, in which event operation should be carried out forthwith,

to prevent progress of facial asymmetry and secondary changes in the cervical spine. The operation should be preceded by instruction in postural exercises, including holdings, and should not be performed before a child can master these. Parents who decline to agree to operation because they are unconvinced of any defect will often appreciate it at once if they are presented with the child's mirror image.

Anatomy.—The contracted muscle is divided a finger's breadth above the clavicle and the surgeon must bear in mind the anatomical relationships at this level. The sterno-mastoid muscle arises by two heads. The



Fig. 38.—Vulnerability of the brachial plexus in subcutaneous tenotomy of the sterno-mastoid. In this boy of 9 suffering from right sterno-mastoid torticollis, A is the sternal head of the sterno-mastoid, B is the clavicular head, and C is the brachial plexus. After the sternal and clavicular heads have been divided this often stands out and may be mistaken for a residual band of fibrosed muscle.

sternal head, rounded and tendinous, is attached to the upper part of the front of the manubrium sterni. The clavicular head, flattened and mostly muscular, arises from the front and the upper border of the inner third of the clavicle. The muscle, in its sheath, is separated from the skin by the platysma, lying in the superficial fascia Its lower part is crossed by the medial supraclavicular (suprasternal) cutaneous nerve. Parallel with the inner border of the sternal head lies the anterior jugular vein, and in relation with the outer side of the clavicular head is the external jugular vein. A small communication between these veins crosses behind the muscle and is the largest vessel that is inevitably endangered in a properly performed tenotomy. The carotid sheath also, with its contents, has a posterior relationship at the level of operation, but lies on a considerably deeper

plane, portions of the sterno-hyoid and sterno-thyroid muscles intervening. The second part of the subclavian artery is separated by the scalenus anterior (anticus); but the transverse cervical and suprascapular (transverse scapular) arteries, and the corresponding veins, lie in front of this muscle behind the lower part of the sterno-mastoid muscle. The subclavian vein lies behind the clavicle, away from the field of operation. The cords of the brachial plexus, emerging from between the scalenus anterior (anticus) and medius, leave the shelter of the posterior margin of the clavicular head of sterno-mastoid obliquely, passing downwards and outwards across the posterior triangle Here they have been accidentally divided in mistake for residual bands of the clavicular head of sterno-mastoid (Fig. 38).

Method.—Both the advantages and disadvantages of the subcutaneous method, which have been discussed, are particularly obvious in this situation. The subcutaneous method is frequently carried out by persons expert in its use, with whom serious accidents appear quite unknown, and the results with cases that are not too advanced are excellent. As a method for general use, it should be condemned as too dangerous in the hands of anyone not trained in, and accustomed to, its performance; and it is also unsuitable when both heads of the muscle are extensively affected. Only the primarily contracted structures, namely the sterno-mastoid muscle (or one of its heads) and the tighter parts of its sheath, should be divided. The secondarily contracted structures are treated afterwards by stretching with active exercises; they are too widespread for division, and the attempt causes disfigurement from one-sided depression of the contour of the neck. *The whole basis of the treatment of established sterno-mastoid torticollis is that the fibrosed sterno-mastoid is too tight for stretching and that the secondarily contracted structures are too extensive for division.* Open operation often leaves an ugly depression where the prominence of the lower part of the muscle should lie—a defect which is less evident after subcutaneous operation, probably because the sheath is better preserved. It is for this reason, even more than the absence of an appreciable scar, that the subcutaneous operation, performed in suitable cases, gives the best cosmetic results.

Subcutaneous operation. Instruments.—In addition to tenotomes, instruments should be available, so that, in the remote event of important hæmorrhage, this could be dealt with by open incision.

Anæsthesia.—Venous engorgement must be avoided. A method dispensing with the anæsthetic mask is a convenience.

Position.—The patient is placed in the dorsal position with a flat sandbag behind the shoulders and with the head projecting beyond the table. The affected sterno-mastoid muscle is rendered taut by the anæsthetist, who holds the head as follows: rotated towards the same side, titled towards the opposite side, retracted, flexed, and displaced towards the same side. One assistant pulls the arms gently downwards, another stands on the left of the neck. The operator stands on the patient's right.

Operation.—The operator's left forefinger rests on the left edge of the contracted *structure and the tenotome is introduced here, less* than a finger's breadth above the clavicle, on the flat, deep to the tendon, and strictly tangentially to the surface. The cutting edge is turned towards the tendon, which is divided by cutting towards the skin. The procedure is repeated through the same opening until all the tight bands have been divided—the sternal head, the clavicular head, or both if both are *contracted. In the division of successive bands, the cords* of the brachial plexus often become taut and stand out almost like remnants of a contracted clavicular head (Fig. 38). The plexus is *avoided by recognition of its obliquity. The tenotome is withdrawn,* and a piece of gauze is applied over the puncture and fixed in place by a length of strapping, 2 in. broad, passed obliquely from the front of the chest *over the dressing and shoulder and down and* across the back. The surgeon takes the head from the anæsthetist and accentuates the posture in which it is being held, while his assistant holds the shoulders. In this way any *slight residual bands are snapped and secondarily* contracted structures stretched. Finally a compression dressing of cotton wool and bandage is applied.

If the operation is carried out as described, the anterior jugular vein is situated too far forward, and the external jugular too far back, to come into the danger area. The communicating vessel between the two, *lying underneath the sterno-mastoid,* is usually small and is only liable to injury if the tenotome is passed rather deeply. If there is a moderate amount of venous hæmorrhage, suggesting the division of a larger vessel than usual, *it can practically always be stopped* by holding a pad of gauze over the spot and pressing well down on to the clavicle.

After-treatment.—Stretching exercises and postural exercises are resumed after about four days, and should be continued until the patient holds the head naturally in the correct posture. These exercises are indispensable; fixation by plaster of Paris in the "over-corrected" position, or suspension by a head halter, is unnecessary and irksome. The results of operation, with appropriate after-treatment, are excellent in cases that are not too far advanced, though the associated facial asymmetry does not entirely disappear.

Open operation. Operation.—A collar incision is made, about a finger's breadth above the clavicle, parallel with the natural creases of the neck and extending from one side of the contracted structure to the other. The skin, platysma and fascia are divided, hæmostasis being secured. The contracted band is *divided with great care* to avoid the important structures in the vicinity. Any bleeding points are secured and tied The platysma is sutured with interrupted stitches of catgut and the skin meticulously *with horsehair, finest* silkworm or nylon. Drainage is not necessary. A compression bandage is applied over gauze and cotton wool.

After-treatment.—The skin stitches are removed after not more

than five days. Exercises are delayed for about ten days. Thereafter the treatment is as after the subcutaneous operation.

Tenotomy of the adductor longus.—The tendon of this muscle together with adjacent parts of the other adductor muscles of the hip (except the pectineus) may be divided in the subpubic region. Because the part is liable to soiling from the excreta and because no important structure is endangered, the subcutaneous method should be chosen, unless exposure is demanded by a concomitant operation, such as obturator neurectomy in the thigh.

Indications.—The operation may be carried out, with or without obturator neurectomy, in cases of spastic paralysis of the lower limb with much adductor spasm. Sometimes it is carried out for adduction contracture of the hip, as in osteoarthritis or old-standing congenital dislocation, and it may form the last stage of an operation, such as arthrodesis of the hip or osteotomy of the upper part of the femur.

Position.—With the patient on his back, preferably on an orthopædic table, the limb is abducted by an assistant. The surgeon stands on the outer side of the limb.

Subcutaneous operation.—The muscle and tendon fibres are divided about a finger's breadth below their origin. The tenotome is passed vertically on the outer side of the adductor longus, which is divided by cutting towards the skin. If the abduction secured in this way is insufficient the tenotome is partially withdrawn and reintroduced about half an inch further laterally. A cut in the medial direction divides a portion of the adductor brevis, magnus and gracilis.

This is one of those tenotomies which may be performed by the alternative method of introducing the tenotome superficially and cutting deeply.

Lengthening the hamstrings.—It is usually preferable to *lengthen the hamstring* tendons rather than simply divide them. It is seldom advisable to treat them all; one or two should as a rule be left intact; otherwise hyperextension of the knee may be promoted.

Indications.—The hamstrings may require to be divided or lengthened for any condition of fixed flexion contracture of the knee joint, and also in cases of spastic paralysis in which there is flexor spasm of the joint and the hamstring muscles consequently require to be weakened.

Anatomy.—The hamstrings consist anatomically of the cords formed behind the knee by the biceps femoris laterally and the semimembranosus and semitendinosus medially. From a surgical viewpoint the gracilis should be added. They are lengthened in their lower part. At the site of operation, the semitendinosus and gracilis are purely tendinous, as their names perhaps suggest; the semimembranosus and biceps present a superficial tendinous part and a deep muscular part. The semitendinosus lies superficial to the semimembranosus, with the gracilis medially. The most important

anatomical relationship is that of the lateral popliteal (common peroneal) nerve, running along the inner side of the biceps tendon; and the other important popliteal structures also are close by. Consequently *subcutaneous* tenotomy of the hamstrings should rarely be undertaken.

Pre-operative treatment.—The patient should be accustomed beforehand to the post-operative splinting and excercises.

Operation.—With the patient prone, the assistant controls the leg. An incision about 3 in. long is made over the biceps tendon, which is lengthened by a sliding operation as for the tendo Achillis (Fig. 40, p. 139), care being taken to identify and protect the lateral popliteal nerve before starting the division. The medial hamstrings can be lengthened similarly through a corresponding incision on the opposite side of the popliteal space. After suture of the tendons, the fascia is repaired separately from the skin to prevent its adhesion to the tendons. After the wound has been dressed, a posterior plaster slab or a Thomas's splint is applied. If there is the slightest doubt about the circulation with the knee extended, the limb should be raised flexed on a Thomas's splint with knee-flexion piece and extended gradually in the post-operative period.

Comments.—Adequate correction often demands also a *posterior capsulotomy of the knee.* Through the same incision, and by working across the back of the joint in front of the contents of the popliteal space, it is not difficult to divide the capsule near its femoral attachment. The importance of respecting the circulation by gradual correction in cases of severe contracture cannot be over-emphasized. The danger of gangrene from its neglect is a real one.

Tenotomy and lengthening of the tendo Achillis (tendo calcaneus). Indications.—This operation is carried out for the correction of talipes equinus In cases of equinus due to spastic paralysis the weakening of the calf muscles caused by the lengthening of their common tendon is helpful in the restoration of muscle balance, but, if excessive, may cause a disastrous condition of spastic talipes calcaneus. In the past, elongation of the tendo Achillis has on the whole been advised too frequently and carried out too drastically in spastic cases, often without proper conservative treatment. In a patient with a paretic quadriceps muscle, usually from infantile paralysis, slight talipes equinus may be the means of locking the knee in walking, and full correction of the deformity may weaken the knee, or, if the gluteus maximus also is paralysed, render the patient unable to walk unaided. Flail foot is more suitably treated by Lambrinudi's arthrodesis (p. 67), which abolishes the lateral instability and also provides a bony block against drop foot. In cases of congenital talipes equino-varus elongation of the tendo Achillis is only exceptionally necessary, and it should never precede full correction of the other deformities, because this depends largely on a reasonably resistant

tendo Achillis. In peripheral vascular disease Boyd* and his colleagues have carried out simple subcutaneous tenotomy of the tendo Achillis in order to diminish the circulatory needs of the gastrocnemius and soleus, and thus abolish the ischæmic pain.

Anatomy.—The tendon is inserted into the lower part of the back of the calcaneum (os calcis, calcaneus), or half way down the posterior aspect of the bone as described anatomically in the conventional equinus attitude. A small bursa intervenes between the tendon and the smooth surface of the upper part of the posterior aspect of the bone. In the adult the tendon is narrowest about 1½ in. above its insertion and is enclosed in a thin synovial sheath for a distance of about 8 in., the tendon being suspended in the sheath by a meso-tendon on its deep surface. The tendinous fibres interlace freely and they extend upwards on the superficial aspect of the muscle for a considerable distance into the calf.

Position.—The patient lies upon his face with the foot projecting beyond the end of the table, or alternatively with the ankle supported by a thick sand-bag. The surgeon stands on the outer side of the limb and an assistant controls the foot.

Simple subcutaneous tenotomy of the tendo Achillis.—This is rarely performed, because of the danger of undue retraction of the upper portion, with consequent excessive weakening and shortening of the calf muscles. It is especially to be avoided in young children, in whom operation on the tendo Achillis is hardly ever justifiable.

Sliding subcutaneous tenotomy of the tendo Achillis (Boyer's operation).—The tenotome is entered on the outer border of the tendo Achillis about ½ in. above the insertion, and the outer half of the taut tendon is divided. The tenotome is withdrawn and re-inserted on the inner side 1½ in. to 2 in. higher up and the inner half of the tendon divided by successive strokes of the tenotome until, with steady pressure on the sole of the foot, the tendon is felt to begin to give way. The tenotome is withdrawn and by continuous steady pressure on the foot the tendon is stretched to the required length. Dressings and cotton wool are applied, followed by a plaster of Paris case from the tips of the toes to the upper calf. The distance between the points at which the tenotome is entered should always be considerably more than the lengthening required. The tendon must not be stretched too far, because an over-lengthened tendon cannot shorten again.

Open lengthening of the tendo Achillis.—In the writer's opinion, this operation is nearly always preferable to subcutaneous tenotomy, over which it has the following advantages: (1) it allows more accurate control of the amount by which the tendon is lengthened, an important matter in all cases and especially spastic ones; (2) the longitudinal part of the division is performed by section instead of splitting, which is difficult to achieve in practice because the fibres are

* Boyd, A. M., Ratcliffe, A. Hall, Jepson, R. P., and James, G. W. M., "Intermittent Claudication. A Clinical Study," *J Bone Jt Surg*, 1949, xxxiB, 325.

not straight and parallel but spiral and interlaced; (3) often prevention of correction by tightness of the capsule at the back of the ankle calls for posterior capsulotomy, which cannot be satisfactorily accomplished subcutaneously. The operation is performed as follows As a tourniquet an Esmarch's bandage is applied, above the knee in order not to compress the calf muscles. A vertical posterior incision over the mid-line of the tendon is made and is terminated below at a higher level than the margin of the shoe (Fig. 39); this gives a better, less ugly and more easily concealed scar than the curved incision often recommended. The edges are reflected with about half the thickness of the subcutaneous tissue, which is very scanty in the lower part. The covering of fat left on the tendon sheath is helpful during its subsequent closure. The incision is deepened to the tendon, and retraction of the sheath is assisted by a few touches of the scalpel. This is introduced on the flat into the substance of the tendon at the middle of its thickness and the tendon is carefully slit coronally into anterior and posterior halves Division is completed by cutting out to the surface above and cutting deeply near the lower end, so that the divided tendon forms two tongues The required lengthening is secured by dorsiflexion of the foot; the two tongues of tendon are then sutured as shown in Fig. 40. The sheath, with its adherent fat, is closed and then the skin. A dressing with cotton wool and a plaster of Paris case are applied as in subcutaneous tenotomy. The Esmarch's bandage is removed.

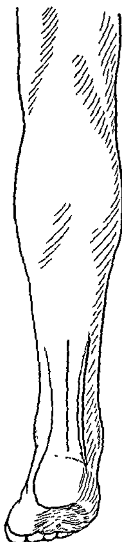


Fig. 39.—Open lengthening of tendo Achillis: incision. The mid-line incision is best cosmetically. If the patient wears a boot, the lateral incision shown is preferable. It may be converted into a flap by incision in a skin crease above the heel, as indicated by a dotted line.

After-treatment.—The plaster case is retained for six weeks in all, being renewed a fortnight after the operation if it has become loose or if the stitches are thought to need removal at this stage.

Tenotomy of the extensors of the toes.—This is sometimes carried out for clawing of the toes, but there are so many other factors in this deformity that the operation alone has little effect. For the second to the fifth toes the operation is done subcutaneously opposite the metatarsal head, the tenotome being slipped under the tendon, which is tightened across the blade by plantar-flexion of the toe and so divided. Tendon lengthening is preferred for the extensor *hallucis longus* because of the uncertainty of union after simple tenotomy.

TENDON SUTURING AND TENDON SHORTENING

Tendon Suture

Indications.—Suture of tendons is indicated in cases of rupture or of division which may have been accidental or carried out deliberately in the course of an operation.

When to suture in cases of accidental division.—It is important to decide whether the tendon should be sutured immediately or after an interval. The advantages of primary or immediate suture are (1) that retraction is easily overcome, and (2) that the patient may be saved a

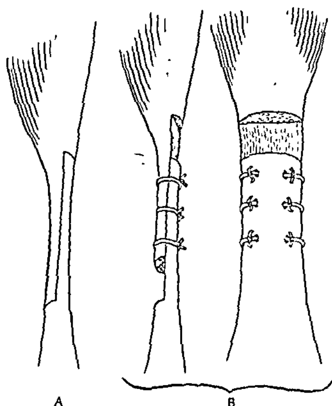


Fig. 40.—Method of lengthening tendo Achillis.
A, *Diagram* of incision in tendon B, *Diagram* of side-to-side suture of lengthened tendon.

second operation. The disadvantage is that accidental wounds are potentially infected, and the slightest infection will almost certainly cause adhesions which will interfere with the subsequent action of the tendon.

Probably the best procedure is to carry out immediate suture in the following circumstances: (*a*) the general condition of the patient is good, (*b*) the wound is reasonably clean; (*c*) the wound is not complicated by wide laceration, contusion or tissue loss; (*d*) the operation can be performed with little disturbance beyond the necessary management of the wound, and without extensive opening up of

tissues; (*e*) adequate facilities for aseptic surgery are available. Suture of a tendon should not be considered a minor operation; it requires adequate preparation, good operation facilities and competent assistance. If these conditions do not obtain it is better to confine the immediate operation to cleaning and usually excision of the wound and careful suture of the skin, repair of the tendon being deferred till the superficial wound has healed. If it heals aseptically, secondary suture of the tendon can be carried out at the end of a fortnight or three weeks. Should it be otherwise, the tendon repair must be postponed until wound healing is satisfactory and all infection overcome. All scar tissue around the tendon must be excised when it is finally sutured.

If there is loss of overlying skin, a tendon should not be sutured primarily, and every possible effort should be made to obtain a full covering of viable skin and subcutaneous tissue by immediate plastic procedures, because a denuded tendon will slough and an unrepaired skin gap will probably become infected. Split skin grafts must not be applied over tendons. In very severe hand injuries, such as "degloving", the usual wound toilet may be followed by burying the damaged part beneath the abdominal skin and superficial fascia, from which it will be possible to fashion a new integument beneath which tendon and other repairs may be carried out later in an aseptic field.

Pre-operative examination.—Before operation in traumatic cases a careful examination must be carried out to determine which tendons are divided and whether other important structures have suffered, for instance the median or ulnar nerve in front of the wrist. The superficial wound may be a misleading guide to the site of division of a tendon unless the position of the part at the time of injury is known, and every effort should be made to find out.

Anæsthesia.—The identification of tendons is facilitated by regional analgesia in a helpful patient.

Suture materials.—For straightforward sutures, No. 40 linen thread has proved satisfactory, with No. 60 for finer work At the present time many surgeons are using stainless steel wire of about 35 gauge because of its non-irritant character. Mechanically wire can be troublesome: under or near the skin, it can be splinter-like, and its very inertness prevents its being discharged by body reaction Hence, when wire sutures are inserted, it is often necessary to provide a means of their subsequent withdrawal. Care must be taken to avoid kinking.

Instruments.—The foundation set should include instruments for fine work and an eyed probe; other instruments frequently required are fine holding forceps and miniature sharp hooks, such as those used by plastic surgeons; long straight Kocher forceps, sutures as described; sandbags; plastic outfit; a giant "hand" (Fig. 45, p. 147) cut from sheet lead, as devised by Fisk*—this can be sterilized,

* Fisk, Geoffrey R., "Splintage of the Hand during Operation," *Lancet*, 1948, ii, 1013.

and the patient's hand lies on it with its flexible "fingers" hooked over any of the patient's that need retraction. Sterile shirt buttons should be available in case it is desired to anchor a suture externally.

Skin incisions for exposing tendons.—Often the position of a wound will influence the placing of an incision. If a wound has to be enlarged it should be extended from one or other end rather than from an intermediate point such as would create a T-shaped or cruciform incision. If possible, incisions should be so placed as to avoid adhesion to the tendon and avoid situations in which keloid formation is frequent. This applies particularly to the hand, where incisions should follow the natural creases whenever possible. Vertical incisions in the hand or its digits must be strictly lateral or medial (Fig. 41). Often, when a tendon has retracted, it should not be "chased" by a single long incision, but, after the site of injury has been exposed, a separate short incision may be made over the anatomical site of the proximal end, which can then be found and drawn down into the original incision by forceps or a threaded probe.

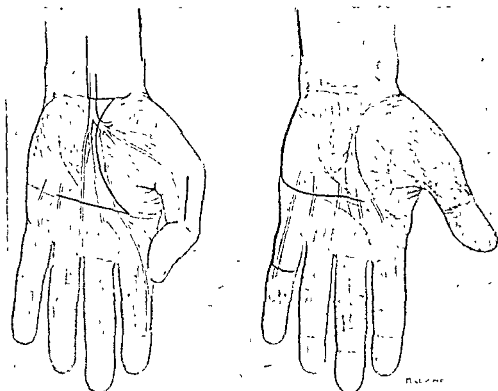


Fig. 41.—Some suitable hand incisions. So far as possible, they are in or parallel with the skin creases or else are strictly lateral. Vertical incisions do not cross straight over skin creases.

Tendons occupying tunnels.—In defining tendons before suture it is important that the surrounding tissue, particularly the synovial sheath, should be damaged as little as possible. If the tendon lies

in a tunnel, an attempt should be made to pass one end through this tunnel without opening it for its entire length. For example, if the flexor longus pollicis is divided opposite the neck of the first metacarpal bone and the proximal part of the tendon has retracted too far to be brought down by flexing the wrist, this part should be found through a separate incision, proximal to the anterior retinaculum (anterior annular ligament); a suture may then be inserted, by which it may be drawn down through its fibrous sheath by means of a probe having an eye, without division of the anterior retinaculum or incision of the thenar muscle eminence, which procedure would not only interfere unduly with the tunnel and its coverings but would also endanger the median part of the nerve supply to the thenar muscles.

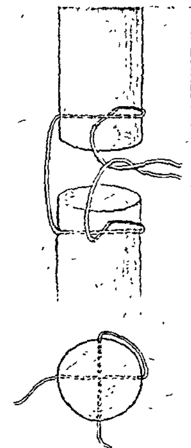


Fig. 42.—Double right angle suture, appropriate for recently divided moderate-sized tendons not subject to much strain.

A special note should be made of division of the flexor tendons of the fingers in the fibrous digital sheaths distal to the transverse crease of the palm. Suture in this situation gives notoriously bad results from adhesions. Probably the following is the best procedure: (1) if the profundus alone is divided, as in injuries distal to the insertion of the sublimis, the condition should nearly always be left alone, because loss of flexion of the terminal interphalangeal joint is not a very serious disability whereas the results of suture are disappointing in the experience of most surgeons; (2) if the sublimis alone is divided, no attempt should be made at suture, because the *profundus tendon is capable of flexing* both interphalangeal joints, and function is practically unaffected; suture will certainly lead to stiffness; (3) if both the sublimis and profundus are divided, the profundus should be carefully sutured, and that part of the sublimis tendon which lies in the fibrous sheath should be excised, except its terminal three-quarters of an inch. This not only simplifies the operation and diminishes the amount of foreign material inserted, but also prevents adhesions between the two tendons and allows more space for swelling of the tendon without prejudice to its blood supply.

Stitches used in suturing tendons.—There are a few indispensable *stitches in tendon surgery*, and it is better to master these in their various applications rather than practise a large variety of suture methods.

(*a*) Ordinary through and through sutures (Fig. 40) tied with reef or surgeon's knots are all that are usually required in tendon lengthening or tendon shortening.

(*b*) The double right angle suture shown in Fig. 42 suffices for the suture of recently divided tendons of moderate size and not subjected to great strain.

(*c*) Bunnell's suture (Fig. 43). It is easiest (and usually permissible) to place a separate stitch in each divided end of the tendon and then to tie each free end of the suture to its fellow. Sometimes it is convenient to insert the stitch in one end, namely that attached to the muscle belly, bring the tails of the stitch through the other end and then on out through the skin where they are anchored over a shirt button. The same means may be used for drawing the end of a tendon into a drill hole in bone, and so on. If stainless steel wire is brought to the surface in this way a "pull-out" suture (Fig. 44) is necessary for the reasons given on p. 140.

Before tying the sutures, especially that just described, it is important to take up all slack, so that the tendon ends cannot slip apart later and leave a gap.

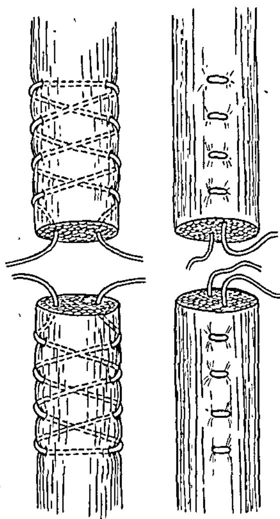


Fig. 43.—Diagram of Bunnell's tendon suture.

Handling tendons.—Roughened tendons become adherent, so that in side-to-side suture, as in tendon lengthening, the apposed surfaces may be roughened with a file or by scraping with a knife. Similar treatment may be applied in fixing a tendon to a bone. In delayed suturing the end should be pared. The problem in most tendon work, however, is not that of making a tendon adhere but the reverse problem of preventing undesirable adhesion. For this reason the surface of a tendon and the paratenon should be injured as little as possible. They should be kept moist and be handled with the greatest gentleness. Rigid asepsis is imperative.

The tendon bed.—Apart from preservation of the paratenon, fat forms the best bed for a tendon as it is the least likely to become adherent. Artificial wrappings have almost always promoted adhesions instead of diminishing them.

Joints.—If the joints concerned have been allowed to stiffen, they must be mobilized before tendon repair is undertaken.

After-treatment.—At first continuity depends upon the stitches, and early movement should be avoided, unless it be essential as in cases of suture within a fibrous sheath; in such a case muscle pull *must be made as small as possible; for instance, after suture of the* flexor tendons, the fingers are left free but the wrist is splinted in full

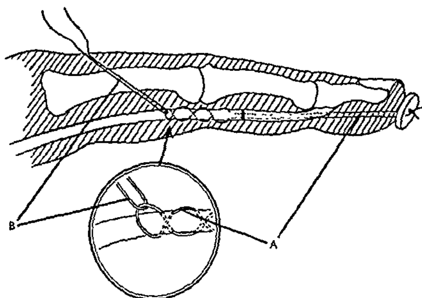


Fig. 44.—A, Bunnell's suture, tethered externally. B, Pull-out wire for withdrawing the Bunnell's suture after it has been cut at A.

flexion, in order to enfeeble the flexor muscles. By the end of three weeks, union is fairly good, and, if necessary, protected movement can be started or an extreme position can be relaxed; for instance the palmar-flexed wrist after suture of the finger flexors, or the plantar-flexed ankle after suture of the tendo Achillis, may begin to come towards the neutral position. Union is not strong till the end of five or six weeks, and some tendons, such as the dorsal expansion of a finger, must be uninterruptedly splinted in the relaxed position for that length of time. At the end of six weeks full use may be allowed in the upper limb, but some protection may still be necessary in the lower limb during walking until good mobility has returned—for instance, after suture of the quadriceps aponeurosis, a plaster of Paris posterior splint till the knee can be bent beyond a right angle, and, after suture of the tendo Achillis, elevation of the heel till the foot can be brought to a right angle—otherwise, a sudden strain may overstretch or re-rupture the tendon.

Some Special Tendons

Suture of ruptured tendo Achillis (calcaneus).—*Recent rupture* of the tendo Achillis is often overlooked, because: (*a*) unlike acute strain of the calf, it is often not very painful or even suspected; (*b*) the sheath fills with blood, which forms a swelling at the site of rupture instead of a gap; (*c*) movements are too painful for an excessive dorsiflexion range or absence of active plantar flexion to be elicited; and (*d*) Hunter's sign of reflex inability to contract the calf muscles is commonly neglected. In recent cases the tendon ends are usually extremely ragged, like the ends of a parted rope. In *old, overlooked cases*, operation often reveals union and, if this is not unduly tenuous, it may be better to carry out tendon shortening, as described later (p. 148), rather than excision of scar tissue and end-to-end suture.

Position.—The patient is placed on his face with the knee semi-flexed and the leg supported by sandbags. The surgeon stands on the outer side of the leg, an assistant controlling the position of the foot.

Operation.—An Esmarch's bandage is applied above the knee in order to avoid binding down the calf muscles. A vertical incision is made over the mid-line of the tendo Achillis, or its outer border, and deepened into the sheath. The blood clot is removed, and the tattered ends of tendon are defined. Bunnell's suture of thread or chromic catgut is inserted in each, the foot is plantar flexed, and the sutures are tied. The union is reinforced by further sutures; plantaris tendon, which is always intact, may be used as a living suture. The sheath, with the subcutaneous tissue, is closed with plain catgut and the skin with interrupted or continuous sutures. A dressing, cotton wool and plaster of Paris are applied with the foot still in plantar flexion, and the Esmarch's bandage is removed.

After-treatment.—At the end of three weeks the plaster and the stitches are removed, a detachable plaster of Paris posterior splint is applied and non-weight-bearing exercises are started. Splinting, frequently removed for active exercises, is continued for a further three weeks with diminishing plantar flexion. Walking is then allowed, with a raised heel until the foot reaches a right angle.

Suture of ruptured quadriceps aponeurosis.—This uncommon injury, which is often bilateral, more frequently befalls older patients than fracture of the patella.

The objects of the operation, the method of repairing the aponeurosis with stout chromic catgut or thread, and the after-treatment, are as for transverse fractures of the patella with separation of the fragments. The upper pole of the patella is often denuded, and must occasionally be drilled to take sutures.

Suture of flexor tendons divided at the wrist.—A serious and frequent accident is division of all or many of the flexor tendons at the wrist from putting the hand through a glass door or window. Often the median

and ulnar nerves are divided also. A decision between primary and delayed suture of the tendons is governed by the general principles already enunciated, with due weight given to the great difficulty of secondary operation. A full primary operation for excision of the wound and suture of all the tendons and the nerves individually occupies about three hours, but this time can be cut down considerably by omitting suture of the sublimis tendons and the nerves. The objections to suturing a sublimis tendon divided in its digital fibrous sheath do not hold at this site, where tendons are far less liable to become adherent, and it is customary to suture the sublimis tendons unless there is special reason for haste. In the case of the nerves, suture should probably be delayed as a rule. The surgeon with great experience of nerve suture and working in a special centre can expect a better result from delayed suture, with all its difficulties, than the average surgeon carrying out primary suture as an emergency, albeit in good surroundings. Moreover, unless a razor-sharp instrument has caused the wound, delay facilitates judgment of the extent of nerve-end to be resected. Whether the nerves are sutured at the time or not their divided ends should, if possible, be tacked together with a silk suture to prevent retraction and to preserve orientation. It is well to have sterilized electrodes and a battery ready in the theatre to help prevent the serious error of mistaking a damaged nerve for a tendon, a surprisingly common happening. In order to link the ends of the severed tendons in correct pairs, it should be remembered that the more superficial of the sublimis tendons go to the middle and ring fingers, the deeper to the index and little fingers. Furthermore, the muscle bellies on the sublimis tendons do not extend so far distally as those on the profundus tendons, which are all rather closely associated except that to the index finger, which usually has a distinct belly throughout. The flexor carpi ulnaris is easily recognized, not only by its position, but by the presence of muscle fibres a very short distance above the wrist. In carrying out this operation, it is probably advisable to use a pneumatic tourniquet above the elbow and to release the pressure temporarily every half hour. After operation the fingers are left free for early movement, with the wrist splinted in flexion by means of a plaster of Paris slab in order to minimize the pull of the flexor muscles or their repaired tendons. This position can be relaxed, and free movement allowed, after three weeks. If the intrinsic muscles are paralysed from concomitant nerve injury, they will recover more slowly than the flexor tendons, and special steps with " lively " splints and physiotherapy are necessary to prevent contractures from muscle imbalance.

Suture of a finger flexor tendon divided in the fibrous digital sheath (*suture of flexor profundus, with resection of sublimis*).—Reference has already been made to the special problems of suture within a fibrous digital sheath in general and of finger flexors in particular; it was pointed out that only the profundus tendon should be sutured and

that nearly all surgeons would be well advised not to suture even this if the sublimis is intact. This is the most exacting of all tendon sutures. Except in children and in the special case of the flexor pollicis longus, the results are so uncertain that there is some case for carrying out a tendon graft (p. 150) rather than suture.

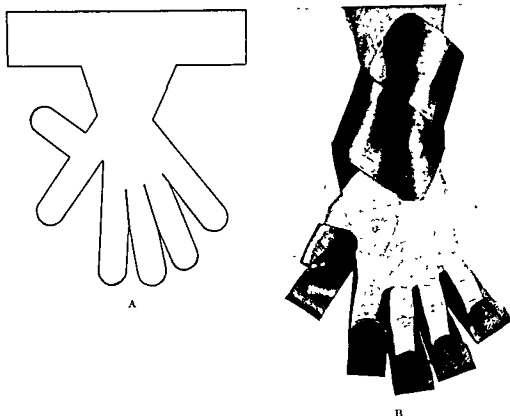


Fig. 45.—A, Malleable "hand" cut from sheet lead. B, Sterilized, it can be placed under a hand to be operated upon, and its "fingers" can embrace and retract the patient's fingers (From *Lancet*, Dec 28, 1948)

Method.—A pneumatic tourniquet is applied above the elbow. The wound is dealt with as described, and is extended as necessary in accordance, so far as possible, with the principles already laid down for hand incisions If the wound is in the finger, as a rule one end should be extended distally and the other proximally by strictly medial and lateral incisions If the wound is in the palm, opposite the metacarpal head, an incision may be made in the distal palmar crease and a flap turned downwards. The flexor fibrous sheath is opened laterally or medially and the sublimis tendon is excised. By flexion of the wrist and compression of the forearm, the proximal end of profundus is brought down, and approximated to the distal end, which may be relaxed by flexing the finger. They are united with the double right-angle suture (Fig 42), the fibrous sheath is left unsutured, and the tourniquet is removed. Hæmostasis is secured mainly by prolonged pressure. The skin is most carefully closed, and dressings and a bandage are applied leaving no dead space. The wrist is immobilized

in full flexion but with the fingers free. The hand is elevated, and an ice-bag may usefully be applied.

After-treatment.—Simple finger movements with the wrist still fully flexed may begin at once. At the end of three weeks the wrist may be freed. Prolonged active exercises are necessary.

Progress.—Often, after very fair progress in restoration of movement, the finger begins to stiffen at the end of four or six weeks, and seems to deteriorate thereafter. This may be only a temporary phase. It has nevertheless been mistaken for a token of failure, and an unnecessary amputation has been carried out.

Division of digital nerves.—An injury that divides the flexor tendons often divides one digital nerve, sometimes both. They should be sutured at the same operation as the tendon.

Tendon Shortening

Overlooked rupture of a tendon may unite—by means of a long scar—so that no gap remains but the muscle is greatly weakened by what amounts to lengthening of its tendon. Unless union is very tenuous, operation may consist in shortening the newly formed tendon rather than excision of the scarred portion and end-to-end suture. The procedure has been mentioned in relation to the tendo Achillis (p. 145), but it is also sometimes carried out on smaller tendons or aponeuroses as for instance in mallet finger that has not been treated successfully at an earlier stage.

A simple method should be chosen. For larger tendons, such as the

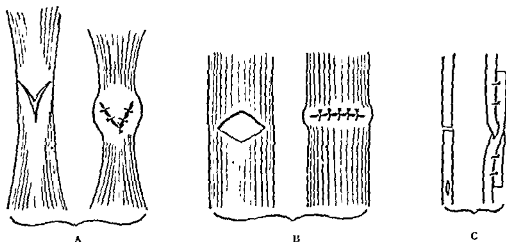


Fig. 46.—Methods of shortening tendons.
A is suitable for large tendons B is suitable for aponeuroses (an overlapping suture may also be used). C is suitable for small tendons.

tendo Achillis, the V-Y method (Fig. 46A) is suitable. For aponeuroses, a diamond-shaped aperture closed by a transverse suture line may be used (Fig. 46B). With small narrow tendons, division may be followed by transplantation of the proximal portion through the distal, combined with side-to-side suture (Fig. 46C).

Old rupture of extensor expansion of a finger. (1) Mallet finger.—Operation has no part to play in a recent case. Conservative treatment has succeeded even when begun as late as six weeks after injury. In old cases it is unwise to attempt to reinsert the dorsal expansion into the terminal phalanx, a plan that is likely to fail and to damage the nail bed. It is better to shorten the elongated expansion over the middle phalanx; with meticulous technique this has succeeded, but it is so uncertain that arthrodesis of the terminal interphalangeal joint is nearly always preferable.

(2) "Boutonnière" lesion.—The dorsal expansion divides into three at the proximal interphalangeal joint; the middle slip is inserted into the base of the middle phalanx as the extensor of the proximal interphalangeal joint; the collateral slips join together again to become the extensor tendon of the terminal interphalangeal joint. Division or rupture of the middle slip causes the reverse deformity to that of mallet finger, with extension at the terminal interphalangeal joint and flexion at the proximal (Fig. 47). The treatment of a recent case is



six weeks' uninterrupted immobilization with the terminal joint flexed and the proximal joint hyperextended. Reinsertion of the middle slip into the base of the terminal phalanx by passing sutures through drill holes in the bone is a very difficult and uncertain procedure. Improvement may be obtained much more simply by sewing the lateral slips together over the back of the joint—closing the "buttonhole" through which the head of the proximal phalanx tends to project.

Reconstruction of Tendons and Tendon Grafting

The use of tendon as suture material has been referred to very briefly in connection with operations for rupture of the tendo Achillis. A free tendon graft can be used in another manner, namely to bridge a gap in a tendon when part has been destroyed or when retraction after division cannot be overcome because of delay. Free grafts of fascia lata can be used in the same way.*

* Turner, G Grey, "The Uses of Free Transplants of the Fascia Lata in Surgery," *Brit. med J.*, 1920, *i*, 79.

A common instance is that of mallet thumb, in which the extensor pollicis longus gives way opposite Lister's tubercle on the back of the lower end of the radius (Fig. 48). Sometimes no cause can be found for this rupture, but in other instances it follows mal-union of a Colles fracture or tenosynovitis, either acute or chronic. The gap may be satisfactorily bridged by a free tendon graft consisting of half the thickness of any of the tendons in the neighbourhood. If these are involved in a chronic tenosynovitis it is preferable to take half the thickness of a healthy tendon such as the peroneus longus. David Trevor* has recently demonstrated equally good regeneration from bridging the gap with nylon sutures!

Often the same purpose as reconstruction of a tendon may be met more simply by tendon transfer. For instance, in the example just given, of rupture of the extensor pollicis longus tendon, the distal

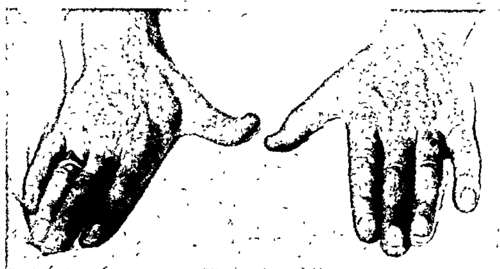


Fig. 48.—Rupture of extensor pollicis longus. The normal (right) thumb can be hyperextended, and the extensor pollicis longus tendon stands out on the back of the hand. The left thumb cannot be extended at the interphalangeal joint, and the tendon does not stand out when the attempt is made.

portion of this can be attached to the tendon of extensor indicis (e.i. proprius) through a transverse incision little more than half an inch long. The transferred tendon is quickly re-educated, so that movements of the thumb and forefinger are soon dissociated. This is probably the operation of choice because of its simplicity and the diminutive scar.

Replacement of a finger flexor tendon by a graft.—An example of tendon reconstruction that needs special mention is the replacement of the flexor tendons of a finger by a tendon graft

Secondary suture of flexor tendons of fingers is usually impossible except by lengthening the profundus at its musculo-tendinous

* Trevor, David, "Rupture of the Extensor Pollicis Longus Tendon after Colles Fracture," *J Bone Jt Surg*, 1950, xxxiiB, 370

junction. It is probably better in most cases to excise the intrathecal remains of the profundus together with the sublimis and to replace the profundus tendon with a graft. In the past it has been customary to use the excised sublimis for this purpose, but it is better to have a more slender tendon, which allows more space for its post-operative swelling within the sheath. Another advantage of a tendon from a distance is that it can be obtained with its paratenon intact. Better tendons for the purpose are therefore the palmaris longus, if present, or an extensor tendon of the third or fourth toe. The tendon is dissected out through a full-length incision, rather than subcutaneously, so that its paratenon is preserved. A Bunnell's suture is inserted in the distal end of the graft, which, after introduction into the thecal sheath, can be fixed directly on to the terminal phalanx by drawing it up to a rawed area by passing the ends of the suture through a transverse drill hole in the bone; or alternatively they may be threaded through a very short distal stump of tendon and then brought out on to the pulp over a button. The proximal end of the graft is attached to the proximal stump by means of a Bunnell's suture, so as to lie proximally in the palm enveloped by lumbical muscle well away from the distal palmal crease and the end of the fibrous flexor sheath. The paratenon should extend over the distal and proximal anastomoses. The graft should be just taut when the wrist and fingers are straight. If the graft is fixed with the finger flexed, the post-operative contraction of the graft will greatly restrict subsequent extension. The wrist is held in flexion with the fingers free, and systematic active finger movements are not allowed for four weeks.

Tendon grafts in tenodesis.—Free tendon grafts may be used as artificial ligaments, either to replace ruptured ligaments or to provide a check to movement in some situation not normally occupied by a ligament. Their importance for this purpose is limited by their ultimate tendency to stretch. Either end of the graft is anchored to bone by passing it through a drill hole and sewing it back to itself. More usual forms of tenodesis are discussed on p. 161 onwards.

TENDON TRANSFER OR TRANSPLANTATION

These terms are applied to changing the insertion of tendons as distinct from the use of tendons, or parts of them, as free grafts (tendon grafting) or as artificial ligaments (tenodesis).

Indications.—A tendon is transferred in order to alter the function of its muscle. For instance, in irrecoverable lower motor neurone paralysis, it may be possible to replace the action of a paralysed muscle by one that has escaped. In conditions in which muscle balance is disturbed by spasm, as for example in spastic paralysis, it is sometimes possible to help the restoration of muscle balance by transferring the tendons of some of the stronger muscles to the weaker. Usually transfer implies an alteration in the alignment of the muscle and its

tendon, as for instance in transfer of the tibialis anterior (anticus) tendon from the inner to the outer border of the foot. In this transfer an invertor becomes an evertor without change in its other action, namely dorsiflexion. Occasionally the action of the tendon is altered without necessarily changing its alignment; for example in transfer of the extensor hallucis longus tendon into the first metatarsal bone, so that it becomes a direct dorsiflexor of the foot instead of an extensor of the toe. Both these examples will be described later. Generally speaking, tendon transfer has been more usefully applied in the upper limb than in the lower, where stability is all-important and arthrodesis of the foot has such an important place. Nevertheless, even here, tendon transfers play a part, notably in the prevention of deformity during growth when arthrodesis is not yet desirable.

General principles to be observed in tendon transfer.

(1) The patient.

(*a*) He must be intelligent enough to collaborate.

(*b*) He must have the will to collaborate.

(2) *The affected part.*

(*a*) In cases of lower motor neurone paralysis tendon transfer should not be undertaken until all the recovery possible by other means has been attained.

(*b*) In spastic paralysis, tendon transfer is a means to an end, namely to facilitate re-education of movement.

(*c*) Any relevant deformities must be corrected before tendon transfer is undertaken.

(*d*) Stiff joints must be mobilized before operation

(*e*) Special care should be taken to determine whether tendon transfer is the best operation, alone or in combination, for the lasting restoration of function in the circumstances of each case; in the foot, for instance, it has been largely superseded by, or used as a supplement to, arthrodesis.

(3) The muscle and tendon selected.

(*a*) It must be capable of being spared from its original function.

(*b*) It must be strong enough for its new task.

(*c*) It must be susceptible of re-education for the new function. Preferably, but not necessarily, it should be a synergist of the one it is to replace, for instance, a wrist flexor readily does the work of a digital extensor.

(*d*) It must preferably be capable of alignment so that a straight pull is exerted in the required direction, and care must be taken to secure this at the time of operation.

(*e*) Only the complete thickness of the tendon should be transferred. The transfer of a portion has proved valueless.

(4) **Technique.**

(*a*) The tendon when transferred must lie in a suitable bed (e.g. subcutaneous fat).

(*b*) The transferred tendon must be securely tethered, being fixed into bone or when this is impossible into tendon. A workmanlike suture to tendon is better than an indifferent fixation to bone.

(*c*) The transferred tendon must be sutured under enough tension. For example, in transferring the tibialis anterior (anticus) tendon to the outer side of the foot, the foot must be held pronated and the tendon held taut while the fixation is made; in transferring a carpal flexor into the extensors of the fingers, the wrist and fingers must be held dorsiflexed, and both the transferred tendon and the extensors of the fingers kept moderately taut during the suture.

(*d*) The tendon and paratenon should be handled with gentle care and strict asepsis.

Methods of tethering a transferred tendon.—The principal methods are:

(1) **Tendon into bone.**—(*a*) The bone at the new point of attachment may be drilled and the tendon passed through the hole and sutured back to itself (Fig. 51). (*b*) A piece of bone, left attached to the tendon when it is separated, may be fixed in a groove cut in the bone at its new point of attachment. (*c*) The tendon may be laid in a slit in the periosteum and sutured to this, which is closed over it.

(2) **Tendon into tendon.**—This is best carried out by leaving the recipient tendon undivided, passing the transferred tendon through a slit in it and suturing them together at the point of passage and beyond (Fig. 49). In separating the tendon, care must be taken to secure enough length to allow for fixation, and occasionally it may be

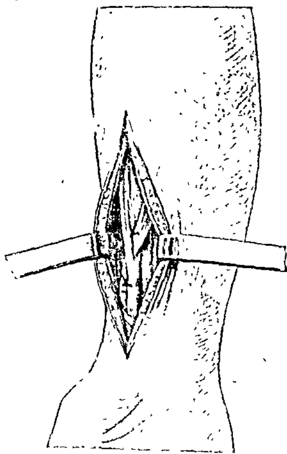


Fig. 49 —Transfer of tendon by passing it through aperture in recipient tendon and suturing it at point of perforation and beyond.

necessary not only to go right up to the insertion of the tendon to be transferred but also *to take a strip of periosteum continuous with it.*

Linen thread (No. 40) and chromic catgut are appropriate suture materials.

Instruments for tendon transfer.—*Foundation set; Kocher's forceps* with long shanks, file, rugine, drills up to $\frac{3}{16}$ in. and drillstock (or awls and Paton's burr), small gouges, small osteotomes, mallet, small aneurysm needle, as for blood-transfusion (Fig. 50); suture thread; Esmarch's bandage and pneumatic tourniquet; plaster of Paris outfit.

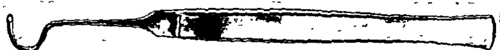


Fig. 50.—Small aneurysm needle, suitable for threading guide sutures through bone. The eye should be oval and as large as possible.

Transfer of the tibialis anterior (anticus) tendon to the outer side of the foot. Indications.—(*a*) To maintain correction in cases of congenital talipes equino-varus in which anatomical correction has succeeded but education of the peronei has failed—or may be expected to fail, as after talo-navicular capsulotomy or capsulectomy (p. 170). (*b*) To restore the balance between invertors and evertors in cases of paralytic talipes varus without fixed deformity, in such cases the danger of "over-correction" should be borne in mind, and tarsal arthrodesis at a suitable age is often preferable.

Anatomy.—The tibialis anterior tendon is contained in a sheath as far as the lower border of the extensor retinaculum (anterior annular ligament), beyond which it lies free; at its insertion it divides into two slips, which pass round the inner border of the foot and are attached to the medial and plantar surfaces of the first (internal) cuneiform bone and the base of the first metatarsal bone The tendon is free *from muscle fibres for a considerable distance above the ankle* and lies close to the shaft of the tibia medial to the other extensor tendons. The peroneus tertius tendon is the most lateral.

Operation.—*An incision is made along the line of the tendon starting* about an inch in front of the ankle joint and continuing as far as the inner side of the middle of the first metatarsal bone. The tendon is exposed, and its two slips of insertion are divided at their attachment to the first (internal) cuneiform and first metatarsal bones. The tendon is then freed as far as the upper end of the incision. A second incision is made on the outer margin of the shaft of the tibia $1\frac{1}{2}$ in. above the ankle joint. The tendon of the tibialis anterior is identified and its extremity is pulled up through the wound. The foot is then turned on its inner side and a third incision is made, extending $2\frac{1}{2}$ in. along the outer border of the foot, the middle of the incision being opposite the base of the fifth metatarsal bone. The skin is dissected

upwards and downwards until the base of the fifth metatarsal and the terminations of the peroneus brevis and peroneus tertius tendons have been identified. A pair of Kocher's forceps is pushed up in the subcutaneous tissue from this incision to that above the ankle, the channel so made is dilated with the forceps and the extremity of the tendon of tibialis anterior is pulled down through the subcutaneous channel. The first two incisions are closed. The tendon is securely sutured to the soft tissues of the outer side of the foot, notably the peroneus brevis and peroneus tertius at their insertions. The last incision is closed. The foot is held in plaster of Paris in a position of pronation for six weeks.

Comments.—(1) In the usual description a fragment of bone is separated with the first metatarsal insertion and transposed with it to a cleft cut in the base of the fifth metatarsal. In practice, any but the minutest fragment prevents withdrawal of the tendon from the first to the second wound, and the seeming refinement is in fact an unnecessary complication. (2) Some surgeons prefer to pass the tibialis anterior tendon through the sheath of peroneus tertius instead of subcutaneously. (3) Often, to avoid over-correction, the tendon is transferred less far laterally.

Transfer of the extensor hallucis longus into the first metatarsal bone (with interphalangeal arthrodesis of the hallux). Indications.—The operation may be performed for dropping of the first metatarsal head with hyperextension of the first metatarso-phalangeal joint and clawing of the great toe, as occurs in pes cavus or in tibialis anterior (anticus) paralysis which so often persists after acute poliomyelitis.

Anatomy.—The tendon of the extensor hallucis longus is enclosed in its own fibrous sheath until after it has passed beneath the inferior extensor retinaculum (anterior annular or cruciate crural ligament). Beyond this it lies in the areolar tissue. As it passes over the base of the proximal phalanx it spreads into a flat expansion which is inserted into the base of the terminal phalanx. On the inner side of the tendon there is often a slip which is attached to the base of the proximal phalanx and may be represented by an additional muscle. The tendon of the extensor brevis digitorum to the first toe, the so-called extensor pollicis brevis, is inserted into the proximal phalanx only.

Operation. (Fig. 51).—A longitudinal incision is made over the line of the tendon from the base of the distal phalanx to the base of the first metatarsal bone. The tendon of the extensor hallucis longus is divided near its insertion and is separated as far as the upper end of the incision. An interphalangeal arthrodesis is carried out by rawing the articular surfaces and holding them in apposition by an axially inserted Kirschner wire, 1·5 mm. thick. The metatarsal bone is cleared with a periosteal elevator at the proposed site of attachment, and two holes $\frac{3}{16}$ in in diameter are bored into the bone, one from the



Fig. 51.—Transfer of extensor hallucis longus into the first metatarsal bone, with interphalangeal arthrodesis of the hallux.

upper, the other from the inner surface, so that they meet within the bone. The end of the cut tendon is *transfixed with a strong suture, which is then threaded* through the eye of a small aneurysm needle passed through the bone from the inner to the dorsal aspect. The needle is then withdrawn so that the suture and the tendon are threaded through the bone. With the foot dorsiflexed, the extremity of the tendon is pulled tight, turned back and crossed under the tendon just above the point at which it enters the bone; there the tendon is securely stitched to itself with two or more sutures of linen thread. The wound is closed and dressed, and *plaster is applied to the leg, foot and hallux. At the* end of three weeks, the stitches and wire are removed, and an unpadded plaster is used for a further three weeks.

Comment.—It is debated how far distally in the first metatarsal bone the tendon should be inserted; distal insertion gives more leverage but a very oblique pull; proximal insertion is probably better. Formerly, the interphalangeal joint was not fused, but the extensor hallucis longus was divided far enough back for its distal stump to be sutured to the tendon of the extensor brevis digitorum going to the first toe, the so-called extensor pollicis brevis; but this was not strong enough to take on its new function of extending the interphalangeal joint, and the operation had a bad reputation for recurrence of deformity.

Transfer of the flexores hallucis and digitorum longus and of the peronei into the tendo *Achillis*.—Reinforcement of the gastrocnemius and soleus by transfer of other muscles that are plantar-*flexors of the foot is a useful procedure in* talipes calcaneus. It is, however, most often combined with tenodesis of the tendo Achillis, and often also with arthrodesis of the tarsal joints. A long incision is made over the lower third of the back of the leg in the middle line, extending just to the top of the heel. Through this the tendo Achillis is exposed and its sheath opened. On the inner side, an incision in the deep surface of the sheath will expose the tendon of the flexor hallucis longus as it winds round the groove in the talus (astragalus). This tendon is pulled up from the sole as far as possible, the foot being plantar-flexed, and the tendon is divided at as low a level as can be reached. The *flexor digitorum longus is then sought* farther forward in front of the posterior tibial nerve and vessels, and that also is divided as it enters the sole On the outer side the two peroneal tendons are similarly found and divided where they wind round the lateral malleolus A small incision is made in the mid-line of the tendo Achillis at the point at which it is attached to the

calcaneum (os calcis, calcaneus). Through this a pair of Kocher's forceps is pushed to the deep aspect and brought out on the inner side, and the tendons of the flexor hallucis longus and the flexor digitorum longus are brought out through the tendon. Similarly, the peronei are passed through it from the outer side. Each tendon in turn is sutured with fine thread to the deep surface of the tendo Achillis, and then beyond the opening in the latter to its surface. The tendons are again sutured to the tendo Achillis, where it is attached to the calcaneum. The foot is held in the plantar-flexed position, and each tendon drawn as tight as possible at the moment of suture. The foot is fixed in the plantar-flexed position in plaster of Paris for six weeks.

Tendon transfer for supple claw toes.*—Claw minor toes, if supple, can be greatly improved by transfer of the flexor tendons to the extensor expansions over the backs of the phalanges, so as to reinforce the action of the lumbricales and interossei. Through a dorso-lateral incision in each minor toe, the flexor sheath is opened; the long and short flexor tendons are detached at their insertions, withdrawn, and sutured to the dorsal expansion over the proximal phalanx as distally as possible, with the deformity corrected. The wounds are closed and dressed with the toes flexed at the metatarso-phalangeal joints. Plaster protection may be used, but stay sutures with splint are not advised.

Transfer of hamstring tendons to the patella.—In paralysis of the quadriceps, probably the only muscles strong enough to be worth transferring are the hamstrings, if unparalysed. This rather unphysiological transfer is rarely justifiable, because (*a*) if the gluteus maximus is powerful, paralysis of one quadriceps is relatively unimportant provided the knee extends fully and the foot is in good position, (*b*) if the gluteus maximus is paralysed, little may be gained by strengthening the knee, especially if it is laterally unstable, (*c*) active extension against gravity is not always achieved, (*d*) it seldom enables a patient previously dependent on an appliance to discard it with advantage. Nevertheless some patients acknowledge an increased sense of stability that they consider worth while.

Some power of active knee flexion should be left; commonly the biceps is chosen for transfer if unweakened, with preferably the semitendinosus too. The anatomy of these tendons is described on p. 135 under tendon lengthening. Each is freed at its insertion (with care to avoid division of the lateral popliteal nerve or the lateral ligament of the knee with the biceps tendon), realigned through subcutaneous tissue, passed through a transverse drill hole in the patella and sutured

A posterior plaster of Paris knee splint is used for six weeks, but re-education may start at three weeks, with protection, and must be assiduous.

* Named after Girdlestone Taylor, R G, "The Treatment of Claw Toes by Multiple Transfers of Flexor into Extensor Tendons," *J. Bone Jt Surg*, 1951, xxxB, 539.

Tendon transfers for radial (musculo-spiral) nerve paralysis.—This operation is reserved for cases of irrecoverable paralysis, which means that many months must be allowed to pass after what has been an anatomically successful nerve suture. It provides a good example of the replacement of paralysed muscles by synergists, and produces remarkable functional improvement, abolishing wrist-drop and enabling the patient to extend his thumb and fingers without concomitant flexion of the wrist.

The transfers recommended* are: (i) pronator teres (pronator radii teres) into extensor carpi radialis longus (longior) and extensor carpi radialis brevis (brevior); (ii) flexor carpi ulnaris into extensor pollicis longus and all the extensors of the fingers—i.e., extensor digitorum (e.d. communis), extensor indicis (e.i. proprius) and extensor digiti minimi (e.d. quinti proprius); (iii) palmaris longus (if present) into abductor pollicis longus (extensor ossis metacarpi pollicis) and extensor pollicis brevis; if palmaris longus is wanting, the ring-finger tendon of sublimis will serve, though theoretically unsuitable.

Before operation the presence of palmaris longus must be confirmed. One carpal flexor, preferably flexor carpi radialis, must always be left; otherwise over-extension of the wrist will seriously impair the grip.

Position.—The patient lies on his back with the forearm upon a side table. The surgeon sits on one side of this table with his assistant opposite. A second assistant is required to hold the forearm and hand in any necessary position.

Operation.—(a) *Transfer of pronator teres into radial extensors.*—Through a vertical 3 in. incision, centred slightly below the middle of the radial side of the forearm, the interval between brachio-radialis (supinator longus) and the extensor carpi radialis longus is opened up. Brachio-radialis is retracted forwards and the radial extensors of the carpus are retracted backwards, revealing the pronator teres at its insertion obliquely into the radius. A tongue of periosteum distal to this is outlined and separated from the bone with the tendon, care being taken to avoid injury to the radial artery which lies, with the nerve, on the flexor aspect. With the wrist fully extended the tendons of extensor carpi radialis longus and brevis are pulled up and are pierced with a knife at a slightly lower level. A Kocher's forceps is passed first through the brevis and then through the longus, and the tendon of the pronator is seized and drawn through the tendons and fixed to each with a couple of sutures of No. 60 thread. If the tail is long enough it is finally sutured again to the brevis beyond the point at which it pierces it. The wound is closed. (b) *Detachment of tendons of carpal flexors.*—The forearm is supinated. A second incision, $1\frac{1}{2}$ in. long, is made over the middle of the front of the wrist and the palmaris longus tendon is divided at its insertion into the palmar aponeurosis (fascia). Through a third incision of equal length

* ... been left and flexor carpi radialis has been transferred to

in the middle of the front of the forearm this tendon is pulled out with a blunt hook. A fourth incision, 8 in. long, is made from the wrist up the medial side of the front of the forearm, exposing the flexor carpi ulnaris, which is separated from its pisiform attachment and from its muscle fibres for a distance of about 8 in. (c) *Exposure of the digital extensors and re-routing of the carpal flexors.*—The forearm is pronated and a fifth, curved incision is made on the back of the wrist, extending from the middle line to the radial border and thence for 1½ in. up the radial side of the forearm. The tendons of abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, extensor indicis, extensor digitorum, and extensor digiti minimi are identified and cleared proximal to the extensor retinaculum (posterior annular or dorsal carpal ligament). From this incision Kocher's forceps are passed subcutaneously, firstly to the (third) incision in the front of the forearm to pull through the tendon of palmaris longus and secondly to the (fourth) incision on the ulnar border to pull through the tendon of flexor carpi ulnaris. All incisions are closed except the fifth. (d) *Suture of the wrist flexors to the thumb and finger tendons.*—The tendon of palmaris longus is then passed through slits in the tendons of abductor pollicis longus and extensor pollicis brevis, the thumb being extended and abducted and tension made on all the tendons. Suture is made as in the case of pronator teres. The flexor carpi ulnaris is passed from the ulnar to the radial side through extensor digiti minimi, extensor digitorum, extensor indicis and extensor pollicis longus tendons and sutured to these, the fingers being held fully extended. The limb is splinted with plaster of Paris which includes the elbow, holding the forearm pronated, the wrist extended, the fingers almost extended, and the thumb extended and abducted.

After-treatment.—Active movements may start at three to four weeks, but a cock-up splint must be retained in the intervals till six weeks from the operation Formal re-education is required for a few weeks only, the patient's unaided efforts being almost sufficient.

Tendon transfer in spastic paralysis of the upper limb.—In this condition, lack of muscle balance tends to produce, among other deformities, pronation of the forearm, palmar flexion and adduction of the hand, flexion of the fingers and folding of the thumb across the palm of the hand. Although the severity of spasticity must set a limit to improvement by any method of treatment, remarkable improvement is possible with graduated wrist splinting and re-education of movements. When the most has been made of conservative treatment, there are some patients in whom the possibilities of re-education may be improved by a well-planned tendon transfer. Examples of transfers are: (*a*) pronator teres into the radial carpal extensors, to diminish pronation and improve dorsiflexion of the wrist; (*b*) flexor carpi ulnaris into the long extensor of the thumb and possibly the extensors of the other digits to diminish carpal adduction and encourage digital extension; (*c*) a combination of the above; or

(*d*) the whole combination described for musculo-spiral paralysis, provided palmaris longus is present.

Tendon transfer for opponens paralysis.—In complete median nerve paralysis the most serious disability is anæsthesia of the index finger, but restoration of opposition improves the function of the hand, and, in incomplete cases with some remaining sensation, the functional improvement is great. The opponens is also often paralysed in poliomyelitis, in which there is no sensory loss but the picture is usually complicated by paralysis or paresis of other muscles; this is seldom so severe as to vitiate restoration of opposition. In systemic nervous diseases (muscular atrophies, peripheral neuritis, etc.) the affection of the other intrinsic muscles and the progressive nature of the disease make operative treatment less promising, but many of these diseases, at first progressive, become almost static, and operation on the hand may prove extremely helpful.

In the past, very good results have been obtained from arthrodesis of the first metacarpo-carpal joint, usually supplemented by a graft between the first and second metacarpal bones, with the thumb in opposition. Many tendon transfers have been attempted, but most have involved use of non-synergic muscles so that ready re-education could not be expected. This difficulty has been overcome in one of the operations described by Bunnell, in which one of the flexor sublimis tendons, usually that of the ring finger, is realigned and re-inserted in such a way as to have an opponens action. It is divided *near its insertion, withdrawn, and then passed round the flexor carpi* ulnaris near its pisiform insertion, which acts as a pulley * Thence it passes subcutaneously across the front of the carpus and back of the first metacarpo-phalangeal joint to be attached to the ulnar side of the base of the proximal phalanx of the thumb. This is much the most promising of the tendon transfers for opponens paralysis, though not applicable in high median lesions or some cases of poliomyelitis in which flexor sublimis is paralysed. The loss of the sublimis tendon from the ring finger causes no loss of function discernible to the patient.

Operation.—Through an incision in the proximal crease of the ring finger, the terminal slips of the sublimis tendon are divided near their insertions A one-inch incision is made in the proximal crease of the wrist lateral to the flexor carpi ulnaris tendon, the proximity of the ulnar nerve being borne in mind The divided sublimis tendon, which lies medial to the tendon to the middle finger and superficial to the tendon to the fifth finger, is drawn up into the wound. A third incision is made over the *medial* (ulnar) aspect of the base of the proximal phalanx of the thumb, which is drilled for reception of the tendon. A Kocher's forceps is passed from this wound subcutaneously across the back of the first metacarpo-phalangeal joint and the front

of the carpus to the second incision. Here the sublimis tendon is passed round the tendon of flexor carpi ulnaris—as through a pulley bounded mainly by this tendon in front, the wrist capsule behind, the pisiform distally, and the muscle fibres of flexor carpi ulnaris proximally. (The pulley effect is reinforced by a tendinous loop of flexor carpi ulnaris, as described in the footnote.) Thence it is drawn, through the subcutaneous tunnel made by the Kocher forceps, to the back of the first metacarpo-phalangeal joint. Here one slip is passed through the drill hole, so that its new insertion is into the medial side of the base of the proximal phalanx. The other slip may be correspondingly attached to the metacarpal neck. The suturing is done with the wrist in full flexion and the thumb in strong opposition. The position of the thumb is maintained with plaster of Paris.

After-treatment.—The limb is elevated for the first 24 hours. The plaster is retained for three weeks, after which exercises begin.

Tendon transfer for clawing of fingers.—The principle described for the treatment of supple claw toes is applicable to supple claw fingers, the flexor sublimis tendons being transferred to the dorsal expansions to reinforce the weak interossei and lumbricals, often with various refinements and elaborations.

Tendon transfers to restore active flexion at the elbow.—The classic operation is Steindler's proximal transfer of the flexor group of forearm muscles.* Often it can usefully be supplemented by proximal transfer of the corresponding flexor origins also. More recently, Clark† has most successfully used the lower part of the pectoralis major to replace the biceps.

TENODESIS

Tenodesis or tendon fixation consists in providing an abnormal bony attachment for a tendon other than in the course of ordinary tendon transfer. Tenodesis can be used for a number of purposes:

(1) The formation of artificial ligaments.
(2) Reattachment of a ruptured tendon.
(3) Fixation of a "snapping tendon".
(4) Improvement of function of a flail hand.

(1) The formation of artificial ligaments.—Quite apart from the use of free grafts of tendon or fascia, a tendon attached near a joint can be given a second bony attachment on the other side of the joint, so that the intervening portion resembles a ligament.

In many elderly people, spontaneous tenodesis of the long head of the biceps occurs from adhesion to the bicipital groove, so that the proximal part of the tendon becomes a ligament of the shoulder joint. In course of time this artificial ligament atrophies and disappears. Although

* These origins are partly tendinous and partly fleshy
† Clark, John M P, "Reconstruction of Biceps Brachii by Pectoral Muscle Transplantation," *Brit J Surg*, 1946, xxxiv, 180.

this was well known, operative tenodesis of the shoulder (Nicola's operation) had several years' vogue in the treatment of recurrent dislocation of the shoulder. Because most tendons atrophy or stretch after being made into artificial ligaments, tenodesis is now almost confined to the tendo Achillis and the peroneus brevis.

Tenodesis of tendo Achillis.—A strip of tendo Achillis, with its lower attachment preserved, may be tethered to the back of the tibia to form a very strong artificial ligament to check dorsiflexion in corrected talipes calcaneus. In a child care must be taken not to injure the lower tibial epiphysis. Equinus deformity may be caused by failure of the artificial ligament to elongate as the bone grows; conversely, early tenodesis may be used to correct calcaneus deformity with growth

Operation.—A vertical incision is made over the lower third of the tendo Achillis in the middle line. A strip is separated from the rest of the tendon from a point about 1½ in. above its insertion upwards as far as it consists of good, strong, tendinous fibres. Here it is cut through, so that a strip of tendon is left attached below but free above. The whole tendo Achillis is now retracted to the outer side; the underlying flexor hallucis longus is exposed and lifted from the back of the lower end of the tibia; a vertical incision is made in the periosteum of the tibia; and the bone is cleared with a rugine. Two separate drill holes are made into the medulla as far apart as the width of the posterior surface of the bone will allow. The strip of tendo Achillis is now passed through these drill holes by means of an aneurysm needle, and a thread is firmly attached to the extremity of the tendinous strip. The foot is plantar-flexed to an angle of 110 degrees; the strip of tendon is drawn tight, passed through a small aperture in the main tendon as near as possible to its lower end, and securely sutured there. The sheath of the tendon and the skin are then sutured, and the foot fixed in the plantar-flexed position. Fixation is maintained for three months. By means of this operation, the strip of tendon is converted into a posterior ligament, which prevents dorsiflexion of the ankle. The remainder of the tendon is left with its normal function, if any active muscle remains. This operation is often supplemented by tendon transfer of the peronei and long flexor muscles of the toes, if not paralysed, into the lower part of the tendon (page 156) at the time of the tenodesis In flail foot tarsal arthrodesis also may be needed

Tenodesis of peroneus brevis.—Nilsonne* has used tenodesis of the peroneus brevis for old-standing rupture of the lateral (external lateral, fibular collateral) ligament of the ankle with consequent recurrent subluxation and instability. Through a curved incision, behind and below the lateral malleolus, the peroneus brevis was divided in the retinacular region. The distal stump was sutured to a groove cut in the outer aspect of the lateral malleolus, and the proximal stump was sutured to the peroneus longus.

* Nilsonne, Harald, "Making a New Ligament in Ankle Sprain," *J Bone Jt Surg*, 1932, xiv, 380

Watson-Jones* has described a similar operation with higher division of peroneus brevis and fixation of the consequently longer distal portion to the lateral malleolus by means of drilling instead of guttering. The tendon of peroneus brevis is separated from its muscle fibres, which are sutured to the peroneus longus. The proximal end of the tendon is then passed forwards through a drill-hole in the fibula about an inch above its lower tip, into the talus (astragalus) just in front of the articular surface of the ankle, out of the talus in the roof of the sinus tarsi, and backwards to be sewn to the periosteum of the tip of the lateral malleolus, or, if long enough, it is passed backwards and upwards through a further tunnel in the fibula to be sewn to the soft tissue behind the lateral malleolus. Eight weeks of immobilization follow.

Tenodesis would seem inferior to Elmslie's† fascial reconstruction (page 178), (*a*) because only the anterior talo-fibular (anterior) fasciculus is replaced, and not the calcaneo-fibular (middle) fasciculus, which also is ruptured in those cases most needing surgery, and (*b*) because integrity of the peronei is important for the physiological protection of the new ligament, as witness the failure of tenodesis when these muscles are weakened by poliomyelitis.

Instead of drilling the talus, Ellis‡ passed the tendon round the ligamentum cervicis, which extends from the outer part of the neck of the talus downwards to the upper aspect of the calcaneum.

(2) Reattachment of a ruptured tendon.—Sometimes a ruptured tendon that cannot be satisfactorily repaired is capable of efficient function if given a secondary bony anchorage. Such is the case with the tendon of the long head of the biceps. This sometimes parts in the neighbourhood of the joint, and the retracted belly of the long head forms a swelling in the arm, which enlarges on flexion or supination of the forearm. The disability is not great and the subjects are usually elderly, so that, in the writer's opinion, operation is not often warranted. Of the various operations proposed, probably the best is tenodesis in the bicipital groove (intertubercular sulcus) because this restores not only tension in the long head but also the correct direction of pull without demanding a great length of healthy tendon. The groove is exposed as in the ordinary anterior (delto-pectoral) approach to the shoulder, two holes are drilled in the floor of the groove, and the tendon is passed through these and then sewn back to itself.

(3) Fixation of a snapping tendon.—Of the many kinds of snapping tendon, a few can be relieved by tenodesis without impairment of their function For instance, in some people the tendon of the long head of biceps acquires a habit of starting from its groove, and the condition becomes painful and disabling. It is relieved by division of the tendon near its origin and tenodesis in the groove exactly as described for cases of rupture.

* Watson-Jones, R, *Fractures and Joint Injuries*, 3rd Ed, 1943 Edinburgh E & S Livingstone, ii, 770.
† Elmslie, R C, "Recurrent Subluxation of the Ankle-Joint," *Ann Surg*, 1934, c, 364
‡ Ellis, V H, personal communication

(4) Improvement of function of a flail hand.—Hendry* has made use of gravity and tenodesis to improve function in the flail hand with mobile joints. If pronation and supination are preserved, all the finger and thumb extensor and flexor tendons are divided above the wrist, and their distal ends are fixed to the radius with the wrist slightly dorsiflexed and the fingers flexed. When the forearm is supinated, the wrist dorsiflexes with gravity, tightening the flexor tendons and so flexing the fingers and providing a grip; conversely pronation opens the hand. If pronation and supination are impossible, even passively, the tenodesis is performed on the flexors alone so that the fingers may be used as a hook.

TENOLYSIS

Tenolysis implies freeing a tendon. Examples are the operations for division of a constricting retinaculum or fibrous sheath as described in the next section, but the term is perhaps more often used for freeing a tendon bound to its bed by scar tissue, for instance after accidental or surgical injury. Operation consists in excision of scar tissue and provision of a suitable bed, such as fat or paratenon. The chief requirements afterwards are elevation, reasonably early movements and prolonged perseverance.

DIVISION OF RETINACULA AND FIBROUS TENDON SHEATHS

A retinaculum or a fibrous tendon sheath has sometimes to be incised to relieve its contents from constriction.

(1) Trigger finger.—This condition arises from the association of a narrow mouth to the fibrous sheath with swelling of a flexor tendon. It may occur in adults—usually women—or in infants, who usually have one thumb, or both, affected. In infants, particularly, the digit often becomes jammed in flexion. Often strapping or splinting the interphalangeal joints for about a month, or even mere temporization, produces relief. Otherwise the proximal end of the fibrous sheath may be slit by operation for a sufficient distance to allow free movement of the tendinous swelling in flexion and extension

(2) C[illegible] [illegible]lovaginitis of the extensor pollicis brevis and [illegible] Quervain's disease).—This condition affects [illegible] is made of diffuse pain over the back of the thumb and first metacarpal bone, which can be provoked by flexion and extension; a hard, tender swelling is found over the base of the styloid process of the radius. This swelling is the greatly thickened radial part of the extensor retinaculum (posterior annular or dorsal carpal ligament) where it bridges the tendons of extensor pollicis brevis and abductor pollicis longus to form a short fibrous sheath as they groove the lower end of the radius. The condition responds poorly to rest, but division of the sheath under local or

* Hendry, A. M., "The Treatment of Residual Paralysis after Brachial Plexus Injuries," *J. Bone Jt Surg.*, 1949, xxxiB, 42

general anæsthesia brings immediate relief and requires no special after-treatment. The superficial branch of the radial nerve crosses the field of operation subcutaneously from above, downwards and backwards; so the incision should only just divide the skin at first, and the nerve should then be defined in the subcutaneous tissue. Care must be taken to divide the whole length of the fibrous sheath, or sometimes sheaths, in which the tendons run, and not to miss any concerned tendon, aberrant or not.

(3) Carpal tunnel compression.—Restriction of space in the carpal tunnel—bridged by the flexor retinaculum, and transmitting the nerves, vessels and tendons from the hand—may cause pain and paræsthesiæ (and sometimes wasting) from median nerve compression, swelling of the fingers from vascular obstruction, and stiffness of the fingers. The symptoms are worst at night, and may be erroneously attributed to a nerve root or trunk. The trouble often affects both hands, and usually no cause is found; but there may be an evident space-occupying lesion, for instance from an old carpal fracture, or the retinaculum may be thickened. Sometimes the synovial sheaths show a non-specific hyperplasia which may well be secondary. The symptoms are relieved by division of the flexor retinaculum. The skin incision skirts the thenar crease, turns medially along the distal volar crease at the wrist and may then be carried proximally for about half an inch. The flexor retinaculum is divided vertically and completely, with care to avoid the median nerve and its branches. The wound is inspected for evident pathological changes, and is closed without suture of the retinaculum.

FASCIOTOMY, MUSCLE SLIDING OR STRIPPING OPERATIONS AND FASCIECTOMY

These are described together because they form alternative or complementary procedures in certain conditions.

Fasciotomy consists in the division of fascia either subcutaneously or by open operation.

A muscle-sliding or stripping operation is one in which a shortened muscle is separated subperiosteally from its origin so that it is able to slide away when the contracture is corrected and obtain a secondary attachment.

Fasciectomy is the complete or partial removal of fascia.

Operations for division of the plantar aponeurosis (fascia). Indications.—The plantar aponeurosis may be divided in cases of pes cavus, whether alone or in combination with other deformities as in talipes equino-cavo-varus. In infants subcutaneous division of the plantar aponeurosis with a tenotome, followed by manipulation, may meet the rare case in which operation is called for; but in older children and adults the contracture of other structures make this inadequate, so that an open fasciotomy and muscle slide operation

known as Steindler's operation is preferred. It is a mistake to expect too much from the operation if bony deformity is present.

Anatomy.—The plantar aponeurosis consists of a central and two lateral parts; the central part is thick and narrow proximally where it is attached to the inner tubercle of the calcaneum (os calcis, calcaneus); it becomes broader and thinner as it extends distally, and divides into five processes, one passing to each toe. The medial part invests the abductor hallucis muscle, and with this muscle extends round the inner border of the foot, and is attached to the flexor retinaculum (internal annular or laciniate ligament). The lateral part covers the abductor digiti minimi (a.d. quinti) and connects the outer tubercle of the calcaneum with the base of the fifth metatarsal bone. The superficial surface of the aponeurosis is connected with the skin by strong fibrous bands; its deep surface gives origin to the muscles that underlie it. These are the abductor hallucis on the inner side, the flexor digitorum brevis in the centre and abductor digiti minimi on the outer side. These muscles are all attached to the under surface of the calcaneum and, in addition, the flexor digitorum accessorius (quadratus plantæ) lying deep to them is attached to this bone. All four of these muscles resist correction of the pes cavus deformity after the plantar aponeurosis has been divided, as do also the long and short (plantar calcaneo-cuboid) plantar ligaments and the inferior part of the capsule of the calcaneo-cuboid joint.

Subcutaneous fasciotomy.—The foot lies upon its outer border on a sandbag. The contracted bands of fascia are defined with the finger, and the tenotome is entered on the inner side of the foot between the skin and the tight band, which is divided by cutting from the surface deeply. The tenotome may be entered at several different points to divide the separate bands, and it may be necessary to pass the tenotome forwards and backwards between the skin and the aponeurosis, in order to sever the fibrous connections between the two.

Open fasciotomy and muscle-sliding operation (calcaneal stripping—Steindler's operation).—An incision* is made along the inner border of the foot starting ¾ in. in front of the prominence of the heel and extending forwards about as far as the level of the navicular (scaphoid) bone. The subcutaneous fat is incised, and the inner border of the central portion of the plantar aponeurosis is defined In severe cases its plantar surface is dissected free from the skin and subcutaneous tissue, backwards to its calcaneal attachment, and forwards to the middle of the sole. The inner part of the plantar aponeurosis and the abductor hallucis are similarly exposed by turning up the skin and subcutaneous tissue on the inner side of the foot. The posterior attachment of the plantar fascia is then separated from the calcaneum with a scalpel, which is passed transversely across the foot just in

front of the medial and lateral tubercles; the incision is carried to the bone and is continued along the inner side of the calcaneum as far as the posterior extremity of the skin incision. The abductor hallucis and other muscles attached to the calcaneum are then separated from the bone with a curved Farabeuf's rugine, the medial and inferior surfaces of the bone being completely denuded. The blade of the rugine is carried forwards until it is felt to enter the calcaneo-cuboid joint. The surgeon will now be wise to insert a finger into the wound. He will probably find it still necessary to divide (*a*) the lateral portion of the aponeurosis where it is attached to the outer tubercle of the calcaneum and (*b*) the posterior attachment of the long plantar ligament. The foot is then straightened manually: a wrench (Fig. 52) is unnecessary if these directions have been followed.

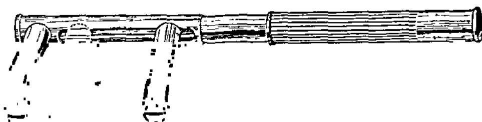


Fig. 52.—Thomas's wrench (Tubby's modification, having curved upper arm).

The skin is sutured without drainage, and the foot is fixed in plaster of Paris in the dorsiflexed position.

In order to avoid damage to the plantar vessels and nerves care should be taken in this operation to keep the knife close to the bone.

After-treatment.—The plaster is retained for six weeks, and is followed by exercises for the intrinsic muscles and a night splint.

Muscle-sliding operation for flexion contracture of the hip (iliac stripping—Soutter's operation).—Flexion contracture of the hip from shortening of the flexor muscles may add seriously to the disability in infantile paralysis and sometimes in spastic paralysis, and great improvement may be secured by Soutter's operation.

Pre-operative treatment.—The treatment here recommended has a two-fold object: (1) to make sure that as much correction as possible is obtained by conservative methods, and (2) to accustom the patient to the position of post-operative fixation. A plaster of Paris case is applied to the pelvis and opposite lower limb with the sound hip fully flexed and the sound knee comfortably flexed beyond a right angle.* The affected limb is not included. The patient is placed on his back in bed and the plaster is fixed with the leg portion supported in such a way as to prevent lumbar lordosis. A Thomas's splint, with knee-piece, is applied to the flexed limb in its deformed position. The limb is gradually extended in this apparatus. When it is clear that full correction cannot be obtained conservatively, on account of soft

* Alternatively, in a child the knee can be splinted in almost full extension, so that the tightened hamstrings control lordosis with much less hip flexion (Harris, E. E., personal communication)

tissue contractures, the plaster case is removed and operation is performed.

Operation.—An incision is made along the anterior half of the iliac crest and continued downwards and slightly medialwards over the front of the thigh. The incision is deepened down to the iliac crest. Tensor fasciæ latæ (femoris), gluteus medius and gluteus minimus are scraped sub-periosteally from the outer aspect of the ilium. The muscles of the abdominal wall are likewise separated inwards and the dissection is continued through the periosteum on the medial aspect of the ilium. Here the iliacus is separated sub-periosteally. The origins of sartorius and the straight head of rectus femoris are dissected off the front of the ilium. While all this is proceeding, the hip can gradually be extended and the front of the ilium protrudes through the wound. The superfluous bone is removed and the muscles are sewn together over the ilium. The superficial wound is closed, a compression bandage is applied, and the pre-operative plaster and splint are re-applied. *The hip should not be fully extended at first* because of the danger of stretching the femoral vessels and endangering the survival of the limb, but in the succeeding few days it can gradually be extended and *finally hyperextended, the patient being nursed* preferably on a fracture bed with the lower half of the mattress removed. The final position should be retained for about six weeks.

Comment.—It is rarely necessary to divide the psoas in order to get full correction, but in some cases, for instance those complicated by pathological dislocation of the hip, an osteotomy of the femur may have to be done at the same time as the soft tissue operation.

Operation for tennis elbow.—The syndrome called tennis elbow is caused by some painful lesion that is pulled upon when the extensor group of forearm muscles contracts or is stretched. The lesion is at the lateral humeral epicondyle in some cases and the back of the radio-humeral joint in others Separation of the muscle fibres from their attachment at these sites relieves the symptoms. Patients should be told that, without operation, spontaneous cure almost invariably takes place in a matter of weeks or months: they usually decide to await the cure rather than seek the immediate relief that the operation offers.

Max Page's* muscle slide operation for flexion contracture of the flexor group of forearm muscles.—In the treatment of ischæmic and other contractures of the wrist flexors in the forearm, their origins may be detached and allowed to slide distally.

Operations on the palmar aponeurosis (fascia) for Dupuytren's contracture. Anatomy.—The palmar aponeurosis consists of a central section, which is thick and narrow proximally where the palmaris longus is inserted (if present), and spreads out below, dividing into

* Page, C Max, "An Operation for the Relief of Flexion Contracture in the Forearm," *J Bone Jt Surg*, 1923, v, 733.

four sections, each of which passes to the corresponding finger. Over the metacarpo-phalangeal joint each process joins the beginning of the digital sheath; it is also connected with the superficial transverse ligament and by deep fibres with the transverse metacarpal ligament. The band passes down on the palmar surface of the finger and, opposite the proximal interphalangeal joint, spreads out in a Y-shape, the two divisions passing to each margin of the middle (second) phalanx. Superficially, the aponeurosis is closely connected with the skin of the palm by fibrous bands and, deeply, it sends connections on either side of the flexor tendons to join the fascia covering the interosseous muscles. The attachment of the thickened bands in Dupuytren's contracture may be equally complicated—portions of the skin may be drawn in by the superficial attachment, the proximal interphalangeal joints may be flexed by contraction of the extensions into the fingers, and the deep connections in the hand render its dissection difficult.

Indications.—The tendency to contracture varies greatly in different individuals. Contractures that progress in spite of conservative treatment by splinting and stretching demand operation before they become so extreme that correction would impair the digital blood supply and amputation becomes the only possible treatment.

Usually only one hand should be operated upon at a time.

Varieties of operation.—Very extensive dissections with the use of grafts of skin and subcutaneous fascia have been advocated, and are sometimes warranted. The smaller procedures are:—

(1) Subcutaneous division of the bands, or *fasciotomy*, and

(2) Open excision of the bands, *fasciectomy*.

The second is the more complete operation and the less likely to be followed by recurrence, although after either method the bands to other fingers may become affected, unless a complete excision of the whole fascia is undertaken. The open operation has also a great advantage that the digital nerves can be exposed and avoided; the denervation of a finger renders it almost useless. Subcutaneous operation therefore should be reserved for cases in which there are reasons for doing as little as possible or the contracture is so great that it prevents sufficient access for the open operation in the first instance.

1. Subcutaneous operation—fasciotomy.—The skin is separated from the contracted bands of fascia by means of a tenotome passed on the flat, and the bands themselves are then divided in several places. Several skin punctures may be needed.

2. Open operation — fasciectomy. — A pneumatic tourniquet is applied. If a limited operation is to be done on the bands to the fourth and fifth fingers, an incision may be made in the distal palmar crease, which is curved, so that a flap of skin can be turned distally. Each band is dissected out, being traced up into the palm, deeply alongside the digital vessels and nerves, and distally into the finger.

If it is thickened here, a strictly lateral incision is made opposite the proximal phalanx. This may be converted into an L-shaped incision by a cut in the palmar crease at the base of the finger, bearing in mind that this crosses the digital vessels and nerves Through this incision the digital band can be removed. This operation is a very limited one, suitable for a chronic case in an elderly person. Usually, a more extensive removal of the palmar fascia should be carried out through some such incision as the L-shaped one of Bunnell which crosses the palm in the transverse crease and then follows the ulnar border of the hand. However limited or extensive the dissection, great care must be taken of the digital nerves. The tourniquet is removed, bleeding is stopped by five minutes' pressure and ligation or diathermy, and the wound is closed. A pressure dressing is applied to the palm, followed by a wrist splint, *but the fingers should be left free.* The patient may move them from the first, but no systematic extension exercises are begun till the wound has healed. Thereafter finger splints are used at night for at least a year, and nevertheless the prognosis must be guarded. In some subjects there is an inveterate tendency to recurrence.

CAPSULOTOMY

It has already been indicated that capsulotomy of the calcaneo-cuboid joint is inherent in Steindler's operation for pes cavus and that capsulotomy of the ankle is sometimes a necessary supplement to *elongation of the tendo Achillis for talipes equinus.*

The following capsulotomy (or capsulectomy) is the most important of the soft tissue operations performed for the correction of congenital talipes equino-varus.*

Capsulotomy of the talo-navicular (astragalo-scaphoid) joint. Indications.—Neglected or recurrent cases of congenital talipes equino-varus in which (*a*) varus or cavo-varus is the principal deformity, (*b*) correction cannot be obtained by manipulation or wedge plasters, and (*c*) immaturity forbids arthrodesis (which often gives extremely bad late results if performed much before completion of growth).

Anatomy.—The talo-navicular (astragalo-scaphoid) joint is a ball-and-socket joint. The ball is formed by the head of the talus (astragalus); the socket is formed in front by the navicular (scaphoid) bone and below by the sustentaculum tali. Alteration of these normal relationships represents a very important part of the deformity in old cases of talipes equino-varus. The navicular bone, displaced inwards and downwards on the head of the talus, is bound to the medial malleolus and the sustentaculum tali by very tough tissue, which may be three-quarters of an inch to an inch thick and is composed of the contracted capsule, with the plantar calcaneo-navicular (spring) ligaments and

* This operation was devised by R. C [illegible] varus," *J orthop Surg*, 1920, ii, 669). [illegible] might accompany it, but he rarely pr[illegible] Brockman (*Congenital Club-Foot*, 1930, [illegible]

the anterior and middle parts of the medial (deltoid, internal lateral, tibial collateral) ligament of the ankle. The tibialis posterior passes over the mass and blends with it.

Operation.—The incision, carried downwards from a point behind the lower end of the tibial shaft, curves forwards beneath the medial malleolus and passes across the tubercle of the navicular bone to the anterior part of the medial (first) cuneiform bone. The tibialis posterior (posticus) tendon, which this incision follows, is defined as far as its navicular insertion which is detached from the bone, the tendon being turned upwards out of its sheath. The anterior part of the medial ligament of the ankle is divided vertically in front of the medial malleolus the knife being carried deeply till it reaches the neck of the talus—often lying at a considerable depth in cases of congenital talipes equino-varus. The joint between the head of the talus and the navicular bone anteriorly and the sustentaculum tali inferiorly is sought, and the ligaments are divided until the navicular bone can be moved outwards and upwards on the head of the talus into approximately the normal relationship. To achieve this it is often necessary to carry the dissection below the joint in order to divide the inferior calcaneo-naviculat ligaments and some of the deep attachments of the tendon of tibialis posterior. This structure is not re-attached. The foot is corrected as far as possible and the wound sutured. The foot, with the lower two-thirds of the calf, is placed in a plaster of Paris case in the " over-corrected " position.

The operation may be combined with Steindler's operation.

After-treatment.—If at operation the skin is too tight to allow full correction, this is secured by a further manipulation three to four weeks later when the wound has healed soundly. Otherwise the original plaster is retained for six weeks unless there is anxiety about the wound. The customary splinting and other precautions against recurrence follow. In a case severe enough to warrant this operation it is usually vain to hope to re-educate the peronei, and the operation should therefore be followed by tendon transfer of tibialis anterior (anticus) to the outer side of the foot (p. 154).

FASCIAL GRAFTING

Though fascia cut to any shape can be used for a graft, it is usually used in strips as suture material or for artificial ligaments.

In some operations a suitable source lies close at hand, as for instance the fascia lata (femoris) if the patella is being dealt with (Fig. 97, p. 262). Usually however fascia has to be obtained from a distance. The site customarily chosen is the fascia lata on the outer side of the thigh, because here it is particularly strong without being unduly adherent and a considerable length is available.

Preparation of strips from the fascia lata (femoris).—These may be obtained by exposure of the whole length of the proposed strips, or by a method that is almost subcutaneous.

The open method has the following advantages: (*a*) it is easier, and allows about four strips to be cut from each thigh; (*b*) it requires no special instruments; (*c*) the gap in the fascia lata can be closed by suture. Its disadvantages are (*a*) the length of time required for closing the long wound, and (*b*) the extent of the external scar.

The "subcutaneous" method has the following advantages: (*a*) rapidity, in skilled hands, and (*b*) the shortness of the external scar. The disadvantages are: (*a*) that it is more difficult; (*b*) that it requires a special instrument; (*c*) that the impossibility of closing the gap left in the fascia lata makes a slight bulge of the vastus lateralis (externus) inevitable (this is of no practical importance in a stable patient); and (*d*) the hypothetically greater risk of hæmatoma.

"Subcutaneous" operation for preparing fascial strips. Operation.—(*A very sharp* fasciotome (Fig. 53) is needed.) A vertical incision, two

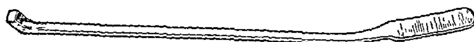


Fig. 53.—Fasciotome (Adams's). A good fasciotome is simple and easily threaded. *All four* sides of the window must have a cutting edge.

inches in length, is made down to the deep fascia in the lowest part of the thigh on its outer aspect. The edges are retracted, and a tongue of fascia lata about 1 cm. wide is dissected up through the length of the wound, being left attached above. The free end is threaded through the eye of the fasciotome and seized in a Kocher's forceps. The surgeon makes traction on this with one hand, while steadily thrusting the fasciotome up the thigh with the other. When, at about 7 to 9 inches, the resistance of the muscle fibres of tensor fasciæ latæ or gluteus maximus is encountered the instrument is withdrawn about half an inch, tension on the fascial tongue is relaxed, the head of the fasciotome is manœuvred into the subcutaneous tissue and then advanced sharply for about an inch, tension on the strip being simultaneously increased. This movement divides the strip at its upper end, and it is withdrawn from below. The strip is freed as much as possible from adherent fat before use. Further strips can be taken. The wound is closed and dressed. Cotton wool should be firmly bandaged to the whole thigh in order to obliterate the subcutaneous channel left by the fasciotome and so diminish the risk of hæmatoma.

The use of fascial strips as artificial ligaments. Reconstruction of the lateral (external lateral, fibular collateral) ligament of the ankle.—Most cases of recurrent involuntary inversion of the ankle are due to chronic sprain—a strain of the anterior part of the lateral ligament—and can be cured by manipulation under anæsthesia followed by appropriate exercises. Some cases, especially after a forcible inversion injury in a young person, are due to actual complete rupture of the

anterior talo-fibular (anterior) fasciculus, and sometimes of the calcaneo-fibular (middle) fasciculus also. The condition should be suspected if pain or swelling are unexpectedly inconspicuous and the range of inversion is increased. The pathology is revealed by *antero-posterior* radiography of the ankles with the feet forcibly inverted. Tilting of one talus (astragalus) through more than five degrees suggests rupture of the anterior talo-fibular fasciculus, and tilting through more than about fifteen or twenty degrees indicates rupture of the calcaneo-fibular fasciculus also. The best treatment is fascial repair of these two fasciculi, as practised by Elmslie.* Two holes, one-eighth of an inch in diameter, are drilled obliquely into the lateral surface of the talus, one above the other, just in front of the articular surface of the ankle so that they meet within the bone to form a canal. A similar, but horizontal, canal is drilled in the lateral surface of the calcaneum (os calcis, calcaneus) opposite the tip of the lateral malleolus and deep to the peroneal tendons. A horizontal canal in the upper part of the malleolus is joined by a vertical one from its tip. Fascia from the thigh is then threaded and sutured in such a way as to replace each of the two fasciculi by a loop—that is a double *strand—of fascia*. Not less than six weeks of plaster immobilization follow, preferably with re-education for the peronei. After removal of the plaster systematic strengthening and mobilizing exercises are given.

Comment.—The modification which V. H. Ellis has used in Watson-Jones's tenodesis of the peroneus brevis (page 169) is equally applicable to Elmslie's operation. The fascia to replace the anterior fasciculus is passed round the ligamentum cervicis instead of through holes drilled in the talus.

The use of fascial grafts as living suture material.—This is described in Chapter XXIII, Vol. II.

OPERATIONS FOR GANGLIA

It is necessary to distinguish between the two totally different conditions to which the term ganglion is applied, namely the " simple " ganglion, the manifestation of a degenerative change, usually in the fibrous tissue of tendon sheaths or joint capsules, and " compound " ganglion, a granulomatous condition of the synovial sheath of a tendon.

" Simple " Ganglia

In considering the treatment of *simple ganglia*, it is important to recognize their pathology. They are the consequence of *mucinous* or *mucoid* degeneration in the *fibrous tissue* of such structures as the capsule of a joint or the fibrous sheath of a tendon, most frequently on the back of *the wrist* and carpus and *the front* of the tarsus and ankle. Mucoid collections run together and so form cysts, and an exceptionally large one *forms* a ganglion. Any treatment less than excision of the whole parent area, may be followed by recurrence from

* Elmslie, R. C., " Recurrent Subluxation of the Ankle-joint," *Ann. Surg.*, 1934, c, 364.

the further collection of mucoid. This does not always happen, but may do so whether the original cyst is excised or merely emptied by rupture or puncture. In deciding upon treatment the surgeon should bear in mind (1) that many ganglia do not cause symptoms, (2) that roughly half will recur after rupture, puncture or local excision, and (3) that wide excision of the mucinous tissue should be regarded as a major procedure as it may involve a wide exposure and the opening of joints; furthermore the extent of change is difficult to determine accurately, and even this operation is quite often followed by recurrence.

The writer's choice would be rupture, if possible, and, failing this, no treatment at all, unless the ganglion were causing enough inconvenience to warrant more troublesome treatment, in which event probably puncture should be preferred as being simple, safe and often successful. Only if these methods fail is wide excision wise. Most writers take a more optimistic view of the open operation and are less in favour of the more conservative methods. Injection of irritants, which was fashionable at one time, has become less popular with a better understanding of pathology.

1. **Rupture by compression.**—The barbarism of striking the part with a heavy object cannot be too strongly condemned. The correct way to rupture a ganglion is to exert firm pressure with the pulp of the thumbs. Rupture is possible only if the ganglion is backed by a resistant part such as the carpus. The momentary discomfort is trivial.

2. **Puncture.**—After the usual skin preparation, a local anæsthetic is introduced into the skin at a slight distance and along a track leading to the ganglion. This is punctured with a large tenotome following the same path, and the contents are expressed. As a ganglion is a degeneration cyst it is useless to scarify the interior.

3. **Wide excision.**—In the writer's opinion this should be reserved for recurrent cases in which the ganglion is giving real trouble. If a general anæsthetic is used a (pneumatic) tourniquet should be applied, or, if a local anæsthetic is used, this should contain an adequate vasoconstrictor and should itself be sufficiently weak to allow safely a wide infiltration Free removal of the ganglion-bearing tissue involves the opening of joints and tendon sheaths, so that the aseptic technique should be irreproachable. Operations of this sort should not be undertaken in the usual circumstances of out-patient departments.

"Compound" Ganglia

A compound ganglion is a granulomatous condition caused by chronic infective tenosynovitis, which is often tuberculous but not always so. It usually affects the sheaths of the wrist flexors and extensors and the peronei. Active tuberculous foci appear to be rarely demonstrable elsewhere, and it is usually impossible to distinguish tuberculous cases from others except by open operation. Although

the patients do not ordinarily require prolonged institutional treatment, sight should not be lost of the importance of general treatment in the sense of good hygiene, liberal diet, fresh air, etc. All require conservative local treatment in the form of rest upon a splint with due care to prevent unnecessary stiffening. Most patients do well with this regimen if continuous and prolonged. Operation may be required: (*a*) to establish a diagnosis by biopsy, (*b*) to repair a pathologically ruptured tendon, (*c*) because of delayed resolution, or (*d*) under economic pressure, perhaps unwisely, in the hope of hastening cure. The objection to operation, apart from doubt as to its necessity, is that it may lead to sinus formation, but the present development of antibiotic substances promises to diminish this danger. The operation is usually extensive, and should not be attempted unless a high standard of aseptic technique is at command. Incisions in the palm of the hand must follow the skin creases, and any incision prolonged into the forearm should not run straight across the wrist but should deviate along the palmar crease for a short distance, so that such an incision is bayonet shaped. Incisions in the fingers should be strictly lateral. Detailed dissection is necessary in order to isolate important structures like the median nerve and its branches, and to remove the granulomatous tissue from the tendons as completely as possible. Often melon-seed bodies are found and have to be removed. These and the excised synovial sheath should be examined histologically and bacteriologically for guidance in subsequent management. Any eroded tendon is repaired or else replaced by tendon transfer. The distal end may be sutured to a neighbour or a gap may be bridged by a free graft from a healthy area, for instance an extensor tendon of the fourth toe; the possibility should be anticipated in carrying out skin preparation and towelling at the beginning of the operation.

CHAPTER V

AMPUTATIONS

By SIR GORDON GORDON-TAYLOR, K.B.E., C.B.
Assisted by A. W. J. CRAFT, O.B.E., and ROLAND N. JONES

" Amputation: One of the meanest, yet one of the greatest operations in surgery; mean, when resorted to where better may be done—great, as the only step to give comfort and prolong life." So wrote Sir William Fergusson in 1867 from his home, 16 George Street, Hanover Square, London. The literature woven round the subject of amputation is indeed voluminous; the story of surgical dismemberment goes back to the days of Celsus and Hippocrates and even beyond. Although Erichsen wrote " Surely it is rather a subject of just pride that the surgeon is able to save the whole of the body by sacrificing a useless limb ", surgeons have never been silent in self-reproach and in expressing their ashamedness over the still-existent necessity for amputation. Guthrie, great and dauntless surgeon that he was, nevertheless termed amputation " the opprobrium of surgery ". John Woodall, whose two publications constituted the " naval surgeon's bible " of the time, said that " it is no small presumption to dismember the image of God ": Kirkland exclaimed: " any blockhead can amputate a leg ": Guy de Chauliac long centuries ago expressed his fear that the patient might bear malice against the surgeon believing that the limb might have been saved. To-day the Law Courts beckon meretriciously to the amputee with the blessed or accursed word—compensation.

Etymological inquiry affords information that the Latin noun and verb were first employed in Ciceronian prose to designate the cutting or pruning of twigs, vines, etc., and the idea of mutilation or anatomical lopping was not implied in its usage until later in the time of Suetonius

The object of an amputation is the removal of a limb or of part of a limb on account of irreparable injury or of disease which has failed to respond to treatment, but many congenitally deformed limbs may also be advantageously amputated and a useful prosthesis substituted for a useless extremity. The level at which an amputation is carried out must, in the main, depend upon the condition of the parts to be removed, but in modern surgery it also depends upon the function desired in the remaining stump. this function differs in the upper and lower limb. In the lower limb the stump must be capable of bearing weight in standing and walking, either directly or through the intervention of an artificial leg or foot. in fact, in modern surgery the level

at which an amputation of the lower limb is carried out and the method of amputating depend largely upon the possibility of supplying a good prosthetic appliance to the resulting stump. A knowledge of the methods of fitting artificial limbs and of their mechanics is essential to a proper consideration of the best methods of amputating.

Examination by limb-fitting surgeons of patients of all categories and from very many hospitals reveals an astonishing variation in the length of stumps involving the same segment of the limb, many irregular badly placed scars, superfluous muscular and fatty tissue left in the stump, and flexion deformities and other stump conditions which somewhat hinder the successful fitting of an artificial limb. It has been said that a good limb-fitter can supply a limb to any form of stump; this may be true, but the object is to fit the best limb. For a number of years considerable thought has been directed to designing the special mechanisms which are necessary in modern artificial limbs: the natural joint which has been removed must be replaced by a mechanism that will give a natural action as far as this can be obtained; stumps which are too long, and indeed many which are too short, preclude the incorporation of these carefully designed and constructed mechanisms.

In the upper limb the function of a stump is entirely different. It may itself be useful either for supporting or for handling and moving an object, or it may be capable of use for the transmission of movement to an artificial arm or to an appliance used instead of an arm. As a support for an artificial arm, the function of the stump is not to bear weight, but to transmit movement; the points of pressure are, therefore, quite different for the two extremities.

If an amputation is carried out under conditions such that healing by primary union is almost certain, it is natural to suppose that the amputation which is to remove the diseased or damaged part and leave the best possible functional use in the remaining stump will be carried out immediately, so that no further surgical treatment of the stump is required. Such an amputation may be called a *final amputation* and should be so designed as to give an ideal stump suitable in every way for a prosthetic appliance. The full rounded stumps which used to be considered so satisfactory are not now looked upon with favour by the artificial leg makers: as a result of the enormous experience derived from two great wars it has been found that a tapering stump with the bone end well covered by skin free from scar is much easier to fit with a prosthesis. If there is a possibility or a probability of sepsis arising in the amputation wound, secondary operations for drainage, removal of necrosed bone or re-amputation will very probably be required. This may result in a shortening of the stump or in an interference with the position of scars and covering of the bone as originally designed.

For an assessment of disability for any specific amputation the Hancock Report* may be studied profitably by all who are concerned

* The senior author (G G -T.) was a member of the Hancock Committee.

with amputation surgery. That part of the Appendix relating to the assessment of disability in some amputations is as follows:—

HANCOCK REPORT—*Part of Appendix*

Part I. Injuries ASSESSED at 20 per cent. and over

Amputation Cases—Upper Limbs

Description of Injury	*Disability of*
1. Loss of both hands or amputation at higher site .	100 per cent.
2. Amputation through shoulder joint . . .	90 per cent.
3 Amputation below shoulder with stump less than 8 inches from tip of acromion . . .	80 per cent.
4. Amputation from 8 inches from tip of acromion to less than 4½ inches below tip of olecranon .	70 per cent.
5. From 4½ inches below tip of olecranon . .	60 per cent.
6. Loss of thumb	30 per cent.
7. Loss of thumb and its metacarpal bone . .	40 per cent.
8. Loss of four fingers.	50 per cent.
9. Loss of three fingers	30 per cent.
10. Loss of two fingers.	20 per cent.
11. Loss of terminal phalanx of thumb . . .	20 per cent. (for either arm)

Amputation Cases—Lower Limbs

Description of Injury	*Assessment of Disability*
12. Double amputation through thigh, or through thigh one side and loss of other foot, or double amputation below thigh to 5 inches below knee	100 per cent.
13. Double amputation through leg lower than 5 inches below knee	100 per cent.
14. Amputation of one leg lower than 5 inches below knee and loss of other foot	100 per cent.
15. Amputation of both feet resulting in end-bearing stumps	100 per cent.
16–19 ———————	

the lower limb. A Thomas' splint can be more rapidly applied and can be replaced by plaster subsequently, if this seems desirable.

9. *Hæmostasis.*—In a case of severe shock few vessels will require ligature, even in an amputation of the thigh, but oozing may take place later. It is therefore rarely advisable in emergency or war surgery to suture the flaps closely without drainage; a piece of corrugated rubber drain at each corner for 24 hours will prevent a hæmatoma and certainly does no harm. If early transport after amputation is probable, it is important not to suture the flaps of an early amputation too closely; and if amputation has been delayed for more than 10 to 12 hours after injury do not perform primary suture of flaps at all.

10. *Avoid massage to the stump like the devil.*—The patient whose stump is massaged and who does not develop a painful limb must be under the special protection of Heaven.

Flaps.—Amputations by circular or oblique elliptic incisions are usually termed "guillotine" operations and should only be considered as an immediate urgency, such as may be necessary in saving life after severe wounds or mutilation of the distal part of a limb. They are primary operations to be followed by a re-fashioning procedure at a later date, when the stump may have to be shortened. Guillotine stumps must of necessity have a terminal adherent scar attached to the truncated bone which, although taking no direct pressure or weight, suffers constant stresses imposed upon it when an artificial limb is being worn.

The ideal scar in a normal "below knee" and an "above knee" amputation should be a narrow linear one near the *posterior lower end of the stump* so situated that it does not come into contact with the inner surface of the socket of the artificial limb. This indicates an anterior flap somewhat longer than the posterior flap. Both flaps should be cut to eliminate any puckering, infolding or "dog ears" along the whole line of the consolidated scar tissue. When suturing the flaps, it is advisable first to insert two or three widely spaced primary sutures to indicate how the wound will close: this will allow the edges to be trimmed to ensure an even scar.

An alternative method is to make two equal flaps which will make a transverse linear scar, but this method has a marked tendency to produce an *adherent scar* over the end of the truncated bone. Such scars break down from the continued up and down movement of the stump in the socket of the artificial limb, termed "piston action," from which it may be deduced that a posterior scar is preferable.

There is some difference of opinion among surgeons upon the advisability of including musculature in the flaps and of sewing it over the end of the bone. The stump end must not be bulbous: the unscarred skin should be freely movable over the stump end, and this is promoted by suturing the deep fascia over the bone end.

Dealing with the bone and periosteum.—The bone must be divided at the correct length in a plane transverse to the longitudinal

is a barbarous mechanism with destructive potentialities. Where competent assistance is available for control of the blood-supply of the limb to be removed, avoid a tourniquet altogether. Many years have elapsed since the senior author has employed a tourniquet for a simple amputation.

4. *Remember the long knife and do not be afraid to use it.*—The employment of a small scalpel to cut through the muscles and connective-tissue structures of a limb is ill-timed and unworthy bravado. The epic operators of the pre-anæsthetic days, famous by reason of necessity for dazzling speed and brilliant dexterity, paid attention to their surgical cutlery, length of blade and sharpness of steel. Amputation knives were forged and fashioned for a purpose. In the name of Heaven use them !

5. *Nerves and blood-vessels.*—Cut through the nerves of the limb with the same circular sweep of the long sharp knife that sections the muscles. Do not add cruelty to your disagreeable task by pulling on, crushing or ligaturing the nerves or injecting them with alcohol. If it be possible to ligature separately from the nerve a bleeding artery coursing within the nerve sheath, take pains to do so. Every pull or insult to the nerve is an added pain to be borne. Blood-vessels are best ligatured with silk, linen thread or cotton. It is probably immaterial whether artery and vein are included in the same ligature or whether they are tied separately.

6. *Hurry up!*—The time taken to perform an emergency amputation *should be reckoned in minutes and not in hours. The surgeon* who spends the best part of an hour or more in performing any of the ordinary emergency amputations of war surgery has not only missed his vocation, but wastes the time of his assistants, fails in his duty to his patient and prejudices the chances of others who are still awaiting surgical aid. One's temptation is to use to the surgical dawdler those words which Cromwell addressed to the Long Parliament, and which were employed again on another more recent Parliamentary occasion: " You have sat too long here for any good you are doing. Depart, I say, and let us have done with you. In the name of God, go ! "

7. *Transfixion.*—In the direst emergency, when life is gravely threatened, speed can be further accelerated by transfixion-flaps, and the limb may be removed at the site of the fractured bone. This is a manœuvre only to be employed in the most exceptional case, but its utility was proved from the personal experience of one of us (G.G.-T.) in the 1914–18 war in the case of men who had been lying out in the shell-holes and the mud of Passchendæle, drinking their own urine. The *sobriquet " Telephonic address, Middle Third " given* to the older writer by the late Major-General Sir Charles Gordon-Watson in the first World War is one of which he is still proud !

8. *Do not waste further time* by putting a desperate case in plaster of Paris for other injuries which may complicate a high amputation of

the lower limb. A Thomas' splint can be more rapidly applied and can be replaced by plaster subsequently, if this seems desirable.

9. *Hæmostasis.*—In a case of severe shock few vessels will require ligature, even in an amputation of the thigh, but oozing may take place later. It is therefore rarely advisable in emergency or war surgery to suture the flaps closely without drainage; a piece of corrugated rubber drain at each corner for 24 hours will prevent a hæmatoma and certainly does no harm. If early transport after amputation is probable, it is important not to suture the flaps of an early amputation too closely; and if amputation has been delayed for more than 10 to 12 hours after injury do not perform primary suture of flaps at all.

10. *Avoid massage to the stump like the devil.*—The patient whose stump is massaged and who does not develop a painful limb must be under the special protection of Heaven.

Flaps.—Amputations by circular or oblique elliptic incisions are usually termed " guillotine " operations and should only be considered as an immediate urgency, such as may be necessary in saving life after severe wounds or mutilation of the distal part of a limb. They are primary operations to be followed by a re-fashioning procedure at a later date, when the stump may have to be shortened. Guillotine stumps must of necessity have a terminal adherent scar attached to the truncated bone which, although taking no direct pressure or weight, suffers constant stresses imposed upon it when an artificial limb is being worn.

The ideal scar in a normal " below knee " and an " above knee " amputation should be a narrow linear one near the *posterior lower end of the stump* so situated that it does not come into contact with the inner surface of the socket of the artificial limb. This indicates an anterior flap somewhat longer than the posterior flap. Both flaps should be cut to eliminate any puckering, infolding or " dog ears " along the whole line of the consolidated scar tissue. When suturing the flaps, it is advisable first to insert two or three widely spaced primary sutures to indicate how the wound will close: this will allow the edges to be trimmed to ensure an even scar.

An alternative method is to make two equal flaps which will make a transverse linear scar, but this method has a marked tendency to produce an *adherent scar* over the end of the truncated bone. Such scars break down from the continued up and down movement of the stump in the socket of the artificial limb, termed " piston action," from which it may be deduced that a posterior scar is preferable.

There is some difference of opinion among surgeons upon the advisability of including musculature in the flaps and of sewing it over the end of the bone. The stump end must not be bulbous: the unscarred skin should be freely movable over the stump end, and this is promoted by suturing the deep fascia over the bone end.

Dealing with the bone and periosteum.—The bone must be divided at the correct length in a plane transverse to the longitudinal

axis of the limb, so as to give a flat level surface. If the bone at the site of section should leave a prominent angle under the skin, e.g. the front edge of the tibia, the prominence should be rounded or sawn off and made smooth for the skin to glide over it. Considerable attention has been paid to the methods of dealing with the periosteum, and it is now recognized that the end of the bone is better left bare for a length of about half an inch above the level of section. This scraping of the periosteum may be done before section, or afterwards. The end of the bone should be slightly rounded off all around its periphery; any medullary cavity becomes sclerosed over. The removal of periosteum tends to prevent any thickening or spur formation: on the other hand, if infection of the bone is probable, perhaps necessitating further surgery, the periosteum should not be scraped away.

Drainage.—The question of drainage in emergency or war surgery has already been discussed. In the surgery of peace, drainage of the amputation stump has not always proved a certain prophylaxis against the formation of a hæmatoma; in many cases it is not only unnecessary, but undesirable from the point of view of the subsequent scar. If, with careful attention to hæmostasis the surface of the wound has been left dry and there appears to be no reason to expect much oozing, the wound in " quiet surgery " may be closed completely; interrupted sutures allow the exit of blood and fluid, thus preventing the formation of a hæmatoma, unless some large vessel recommences to bleed. The pathological condition which rendered the amputation necessary may be responsible for fragile blood vessels in the musculature, in which case drainage may demand careful consideration to prevent the contingency of having to open part of, or possibly the whole, wound. Each case must be judged individually, care being taken that there is no appreciable deformation of the scar where the drainage tube is placed.

AMPUTATIONS IN THE UPPER LIMB

Amputations of fingers and hand.—Rank and Wakefield stress certain principles in connection with sites of election for finger amputation. (1) conservation of length is paramount in the case of the thumb. (2) Amputation stumps of the index and little fingers which do not include a mobile proximal interphalangeal joint are generally redundant and of more nuisance than worth. (3) Remnants of the middle and ring fingers are of great value to a hand in stabilizing the position of the index and minimus and maintaining the integrity of the transverse arch. Embarrassing adduction deformities develop when medius or annulares are amputated through the metacarpo-phalangeal joints. (4) The integrity of the metacarpal heads and transverse metacarpal ligaments is important in the use of the palm during manual grip. These structures should not be lightly interfered with in a manual worker. (5) Although amputation of the index and little fingers

through the metacarpo-phalangeal joint leaves knobs which are unsightly, and the appearance can be improved by a proximal amputation through the metacarpal bone, this should never be done by election at a primary emergency operation, but only by request as a secondary procedure.

A clumsy disarticulation of a finger or portion of [illegible] n abomination in the eyes of any onlooker [illegible] ship of bony prominen[illegible] neighb[illegible] nes[illegible] ate respective [illegible] distal to the *corresponding knu*[illegible]

(*a*, [illegible] distal digital flexure line on the palmar surface of the finger is slightly further from finger tip than the underlying joint.

(*b*) The intermediate digital crease is typically double, and it is the line nearer the finger tip which more nearly marks the level of the joint.

(*c*) The basal palmar creases are situated nearly $\frac{3}{4}$ inch nearer the finger tip than is the metacarpo-phalangeal joint.

Digital amputation stumps are best covered by the more bulky flaps obtainable from the palmar aspect than by dorsal flaps: dorsal scars which are not liable to be pressed upon during moments of opposition or gripping are infinitely preferable to terminal or palmar scars.

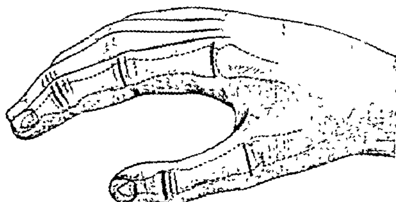


Fig. 54.—Level of metacarpo-phalangeal and interphalangeal joints in relation to creases of fingers.

Amputation at the distal interphalangeal joints.—The terminal phalanx is acutely flexed and the knife enters the joint from the dorsum; after dividing the lateral ligaments the knife is lateralized and with a sawing movement is carried towards the finger-tip close to the bone.

When the flap is of sufficient length, the knife is brought out on the palmar surface; the flap is sutured in position. As a rule, no vessels require ligature This method is most often indicated in crushes of the dorsal aspect of the last phalanx and in necrosis resulting from a whitlow.

For amputation through the *middle or through the first phalanx or at the proximal interphalangeal joint*, a palmar or dorsal flap or lateral flaps may be used. The skin-flap or flaps should first be cut, the bone divided or the joint disarticulated, digital vessels ligatured and digital nerves shortened as in any other amputation. It is unnecessary to preserve the flexor tendons and suture them to the stump (1) because amputation through the middle phalanx proximal to the point of attachment of the flexor sublimis tendons is undesirable, the resulting stump being too short to be useful, (2) because the first phalanx is flexed by the interossei and (3) the suture of tendons across the ends of finger stumps limits movement.

Amputation at the *metacarpo-phalangeal joint* is best carried out through a racket-shaped incision, the circular part of which passes round the palmar aspect of the finger level with the lower edge of the web, the vertical incision lying on the dorsal aspect over the middle of the head of the metacarpal bone. Alternatively, lateral flaps may be used or, if necessary, a flap from either dorsal or palmar surface. It is important to preserve flaps of ample length, otherwise a contraction of the scar may interfere with free abduction of the neighbouring fingers. The flaps having been cut, the extensor tendon is divided over the back of the joint, the joint opened from the dorsal surface and the phalanx disarticulated, the knife being kept close to the bone. The digital vessels may require ligature and the digital nerves should be shortened. Drainage is unnecessary, unless the wound is likely to be infected.

In the index finger it is better to use lateral flaps, cutting a longer flap from the radial side of the finger, the incision on the ulnar side being carried close to the web between the index and second fingers. Thus the scar will be left in a more protected position. Similarly, in the little finger a longer flap should be cut from the ulnar side.

Amputation of finger with metacarpal bone.—The removal of the finger with a portion of its metacarpal bone is sometimes required for injuries which have involved a fracture of the metacarpal with coincident injury of the flexor tendons of the finger. If the tendon injury has left a useless finger, it may be advisable to amputate through the metacarpal, but if the fracture has united in a way which does not interfere with the function of the rest of the hand, such an amputation is best carried out through the metacarpo-phalangeal joint. When the metacarpal bone is united with angulation or shortening or when non-union has resulted, the removal of a part of the metacarpal bone is advisable. Similarly, it may be advisable to amputate a finger with a portion of its metacarpal bone in cases of tuberculous disease or osteomyelitis of the latter bone. Seldom, if ever, is it necessary to remove the entire metacarpal bone including its base; the function of the hand is far less interfered with, if the carpo-metacarpal joint can be left intact. In injuries which have involved amputation of the index and middle fingers and in which the metacarpal bones of these fingers

have been damaged, it is sometimes advisable to remove the greater part of these bones, so that there is left a wide cleft between the thumb and the ring finger: a hand remains which resembles the congenital lobster-claw deformity and which proves very useful.

The amputation through the metacarpal is best carried out through a dorsal incision extending vertically along the length of the bone, completed by an elliptical incision carried from the mid-point of the dorsal aspect of the head of the metacarpal downwards just below the web of the finger, circling the palmar aspect at the lower level of the web and carried back along the same lines on the opposite side of the finger. The extensor tendon should be divided at the level at which it is injured or, if it is uninjured, at the level of the neck of the metacarpal bone. This low division of the tendon is advisable because of the linking up of these extensor tendons together on the dorsal aspect of the hand. The metacarpal bone is then exposed by a vertical incision through its periosteum; the latter is stripped back from the shaft, the knife being used only to disarticulate the head and to complete the removal of the base of the first phalanx from the neighbouring tissues. The metacarpal is then divided with saw or bone-forceps at the selected level, and the flexor tendons are cut near the distal extremity of the wound. The point of division of the metacarpal bone should be just proximal to a fracture or to any area of disease. If sepsis or tuberculous disease renders it inadvisable to preserve the periosteum, the amputation should be carried out in the same way, but the metacarpal bone should be separated from its surroundings by careful dissection with the knife instead of by stripping the periosteum from it. A subperiosteal removal is the better method, since it interferes less with the rest of the hand and is particularly indicated for the metacarpal bone of the middle finger, because the attachment of the transverse head of the adductor muscle of the thumb is not interfered with. If the removal of the entire metacarpal bone is necessary, the incision must be carried a little farther towards the wrist, and the base of the metacarpal carefully disarticulated from its attachments to the carpus and to the neighbouring metacarpal bones. In these amputations the digital arteries and nerves are found and divided near the root of the web of the finger. Except for veins on the dorsal aspect of the hand, no other vessels should require ligature. Drainage is only necessary in cases of sepsis. A splint should be applied for the first few days.

Amputation of the thumb.—Preservation of the thumb or of any portion of it is even more important than preservation of the fingers. Any part of the thumb, even if its remaining joints are stiff, is valuable: in fact partial amputation of the thumb is so rarely called for that the textbook descriptions of set amputations seem almost undesirable. When the thumb must be amputated, it will be for injury or disease so severe that a set operation is very unlikely to be practicable. Even then, every possible portion should be kept, the stump being covered

with skin obtained from any available part or, if necessary, taken by a pedicle graft from some other area.

The terminal phalanx of the thumb is removed in a manner exactly similar to that described for amputation of the corresponding phalanx of a finger. At the metacarpo-phalangeal joint the best flap is one cut as long as possible from the palmar aspect, with, if necessary, a short posterior flap; the scar is thus brought on to the posterior aspect of the stump, where it is least inconvenient. In amputating through these joints, the attachments of the abductor pollicis, flexor brevis pollicis, and adductores pollicis should be preserved, where possible, by suturing them over the head of the metacarpal bone to the extensor expansion on the back of the thumb.

Amputation of the thumb with the metacarpal bone is very seldom indicated, but when it cannot be avoided every possible portion of the bone should be preserved. Formal amputation would be carried out by a racket-shaped incision of which the vertical limb is dorsal, the bone being removed by a close dissection, leaving the muscle attachments as far as possible undisturbed. Such an amputation should seldom, if ever, be required.

Amputation through the carpus and metacarpus.—In injuries of the hand which necessitate the removal of all the fingers and the thumb, the retention of some of the metacarpal bones or even of the carpus alone is worth while, if skin is available to cover the stump. It is not possible to give instructions for amputation in this region, because in each case the operation must be carried out in such a way as to retain as much as possible of the hand and to utilize all the skin available.* It is particularly important to retain the attachments of the flexor and extensor muscles of the carpus to the bases of the metacarpal bones and if the long flexor and extensor tendons of the fingers are intact, they also may be retained and attached into the bones of the stump. These latter tendons should be picked up with light forceps at an early stage of the operation, before they are completely cut through, or they may retract into the forearm so that they cannot be reached without reflecting the flap still further. A stump in which the wrist joint and the first row of carpal bones are intact will presumably be mobile at the wrist, and this stump can practically always be used actively by the patient. It may, in addition, be useful to work an artificial hand.

Amputation of the forearm (below elbow amputation).—Amputation through the forearm is most likely to be required for extensive injuries involving the wrist joint and hand, and for advanced tuberculous disease of the wrist. As much of the forearm as possible should always be preserved, artificial limb makers prefer a stump at the level of the junction of the proximal two-thirds and the distal third of the forearm

* [illegible] can sometimes be covered with skin from [illegible] eboning), together with the [illegible] ea in the palm, being fixed [illegible] worth while sacrificing the little finger for the sake of its skin This is a most valuable expedient in hand injuries

(7 inches below the olecranon). Muscles which rise above the elbow joint should, as a rule, be retained and their fascia sutured across the ends of the bone. Any flaps available may be used but equal antero-posterior flaps with rounded outline are particularly suitable. The skin of the forearm is soft and flexible, so that short flaps will suffice.

An amputation with equal antero-posterior flaps is carried out as follows. The limb is held out at right angles to the trunk, the forearm being fully supinated. The flaps, semicircular in outline, are marked out and the skin reflected: the muscles are divided circularly, just beyond the level of the base of the flaps. They retract upwards slightly, and the periosteum is then stripped down and the bones cut across at the level of the base of the flaps. The vessels are tied, the median, ulnar, radial and interosseous nerves shortened, and the skin sutured with drainage. Special care should be taken to remove any periosteum which might lie across between the bones, and to fix the stump, until it is completely healed, upon a splint in a supinated position. The object of this is to guard against fusion of the ends of the bones, which would abolish pronation and supination.

An amputation which leaves a very short forearm stump has certain objections from the point of view of fitting an artificial limb. When only about 2 inches of ulna remain, flexion of the arm at the elbow brings what was the distal end of the stump into the same line as the anterior surface of the arm, so that the forearm stump practically ceases to exist and no artificial arm bucket can hold upon it. When the stump is a little longer, i.e. about 3 inches of ulna, a very small hold for the bucket remains, but owing to the contraction of the muscles attached to the internal and external condyles of the humerus the antero-posterior diameter of this forearm stump increases as the elbow flexes, so that a bucket which fits well in the extended position is too tight when the elbow is flexed. Because of this trouble, no amputation should be carried out which leaves less than 2 inches of ulna. When 3 inches can be left, the amputation is useful in spite of the difficulty in fitting.

Amputation through the arm (above elbow amputation).—Amputation may be carried out through any point in the humerus, but the junction of the proximal two-thirds and the distal third (about 8 inches below the acromion) is the best level. If less than 1 inch of bone is left beyond the axillary folds, the stump will probably not hold an artificial limb with a mobile shoulder joint, but a small remaining portion of the humerus should nevertheless be preserved, since this leaves the shoulders more symmetrical: when the shoulder joint is disarticulated, the acromion process forms a sharp prominence which is both ugly and troublesome Amputation through the arm may be required for injuries or for new growths involving the upper part of the forearm and for extensive disease of the elbow joint, whether tuberculous or septic.

Any flap may be used, but a circular amputation is as good as any.

Owing to the extensibility of the skin of the arm very little bone need be sacrificed, as the skin can be pulled down and sutured when the bone has been divided almost at the level of the skin-incision. The skin and muscles should be divided down to the bone with one circular sweep, the periosteum removed for half an inch above the proposed level of bone section and the bone then sawn across. The brachial and profunda arteries and the basilic and cephalic veins require ligature; the median, ulnar, musculo-spiral, musculo-cutaneous and internal cutaneous nerves require shortening.

Disarticulation at the shoulder joint.—Disarticulation at the shoulder joint leaves a stump upon which an artificial limb can only be fitted as an ornament. Amputation through the shoulder joint is required only in extensive compound injuries which destroy the head of the humerus, but leave available skin capable of covering the stump; and in malignant tumours of the humerus.

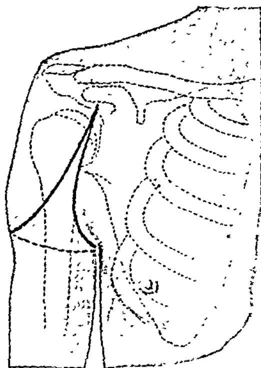


Fig. 55.—Amputation through shoulder joint by anterior racket-shaped incision.

The flaps used to cover a shoulder-joint amputation must depend upon the skin available. If skin is available in the right part, the following modification of Spence's operation appears the simplest. (Fig. 55.) The arm being slightly abducted and rotated outwards, a vertical incision is made from the coracoid process in the line of the arm as far as the level of the anterior axillary fold. It then curves outwards across the lower part of the deltoid, round the arm at the level of the posterior axillary fold, across the axilla, and back with a slight curve upwards to join the original vertical incision. The antero-internal flap is dissected back a short way and the pectoralis major divided. The axillary vessels are then found and are divided between ligatures, and the main brachial nerves cut. The postero-external flap is dissected upwards, the deltoid being retained in the flap. The shoulder joint is opened from the front, the long and short heads of the biceps being divided in the process The muscles attached to the tuberosities are cut, and also those inserted into the bicipital groove and its posterior margin. The humerus is then removed, bleeding vessels are ligatured, and the flap sutured with drainage. Retention of the deltoid leaves a slightly more rounded shoulder than if it is removed.

The indications for the employment of the Furneaux-Jordan technique must be as rare in amputation through the shoulder joint as in the operation which bears his name for disarticulation at the hip joint. In past days, it was recommended for cases of extensive osteomyelitis or necrosis of the humerus, but such cases are very rare nowadays and it is also dubious whether the Furneaux-Jordan method is less productive of shock.

Interscapulo-thoracic amputation. (Figs. 56-59).—Removal of the whole upper limb with the scapula is usually indicated in malignant disease of the upper end of the humerus involving the shoulder joint or the muscles around it or of the scapula itself. The operation should be carried out as a deliberate dissection, an ordinary large scalpel being used. Perhaps the more popular method is that of Berger, in which the subclavian artery and vein are ligated at an early stage of the operation.

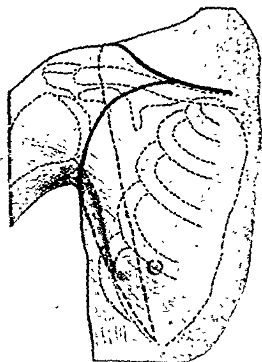


Fig. 56.—Lines of incision in cutting flaps for interscapulo-thoracic amputation.

The patient should be near the edge of the table, so that the shoulder overhangs, a sandbag being placed behind the opposite shoulder. An incision is first made along the upper border of the inner two-thirds of the clavicle. Through this incision the clavicle is exposed, its middle third cleared, and the bone cut through with a Gigli's saw. The outer half of the clavicle is pulled forcibly upwards and its under surface stripped: the outer end is then cut through, the middle portion of the bone being removed. The subclavian vessels and brachial plexus are now exposed, the artery and vein are ligated in two places opposite the first rib, and divided between the ligatures. It is usual to divide the artery first, raising the arm so as to empty it of venous blood before dividing the vein. An injection of 2 per cent. novocain into the main trunks of the brachial plexus at this stage of the operation will diminish the shock involved in the subsequent division of these nerves. The suprascapular and posterior scapular arteries are picked up in the posterior triangle and ligated.

The anterior flap is next completed by carrying the incision from the clavicle opposite the coracoid process downwards across the anterior axillary fold, obliquely across the axilla down to the inferior angle of

the scapula, an assistant manipulating the arm so as to facilitate the cutting of the flap, which is reflected inwards and downwards. The pectoralis major muscle may be retained in the flap and divided close to the humerus, but for malignant disease in the neighbourhood of the shoulder joint it is safer to reflect a sufficient cutaneous flap inwards and to divide the pectoralis major and minor closer to the thorax. The axilla is now exposed, the nerves are divided high up, and the rest of the axillary contents (including fat and glands) dissected downwards in one mass. The arm is then adducted across the chest and the

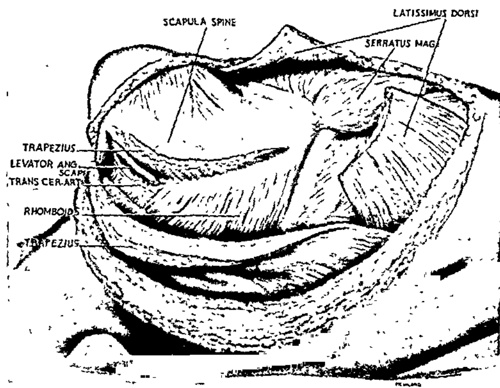


Fig. 57.—Interscapulo-thoracic amputation by the posterior or Littlewood approach. The skin incision is of course the same as employed in the anterior approach. The upper extremity is pulled forward and the trapezius and latissimus dorsi have been sectioned.

posterior incision made; this extends from the outer end of the clavicle, thence directly downwards to the inferior angle of the scapula: this second flap is reflected backwards as far as the vertebral border of the scapula The limb is then removed by rapidly cutting through the trapezius levator anguli scapulæ, rhomboids, serratus magnus, and latissimus dorsi. As these muscles are cut through, a few small vessels will need to be picked up and ligated, and the posterior scapular artery will be divided and require ligature, unless it has been already found in the posterior triangle The large raw area left should be carefully inspected, and bleeding-points looked for, the wound can then be sutured with drainage.

The Littlewood technique has the weighty support of Sir Harry Platt, although one of the authors (G.G.-T.), from a not inconsiderable experience of the amputation, has a decided preference for the Berger operation.

The incision marking out the two flaps, the cervico-scapular and the anterior or pectoral, resembles almost exactly the Berger; it is only in the order of the deeper procedures that the techniques differ. In the Littlewood operation the posterior skin-flap is rapidly reflected towards the vertebral column, exposing the muscles overlying the

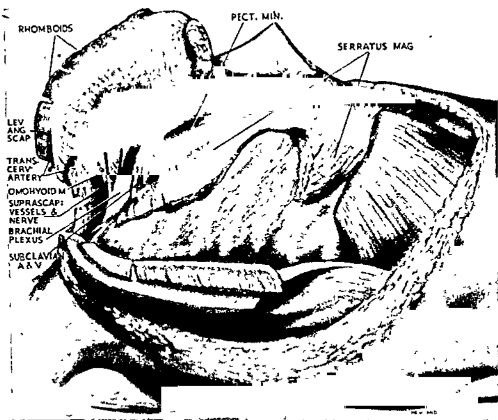


Fig. 58.—Division of levator scapulæ, rhomboids and serratus anterior; exposure of brachial plexus and subclavian vessels from behind.

scapula and connecting that bone with the spine. The trapezius and latissimus dorsi are divided: next the knife divides the levator scapulæ and the rhomboids: traction is exerted on the scapula and the serratus anterior is put on the stretch and divided: the posterior belly of the omo-hyoid at the cephalic extremity of the wound is cut through.

Attention is next directed towards deepening that part of the incision which represents the handle of the racket-shaped incision: the tissues are separated carefully from the middle third of the clavicle, which is divided by a Gigli saw at the junction of its inner and middle thirds, the subclavius muscle is carefully torn through, and the whole upper extremity and shoulder girdle falls away from the trunk. The

brachial plexus and subclavian vessels now remain the sole bonds connecting the shoulder girdle with the trunk. The surgeon working forwards next divides the nerve plexus after preliminary injection with novocain; then the subclavian artery is sectioned between ligatures and finally the subclavian vein. The anterior or pectoral flap is rapidly fashioned, the pectoral muscles being divided at an appropriate distance from the limb which is undergoing amputation. The edges of the large wound left after removal of the limb and shoulder girdle are now approximated and sutured with drainage.

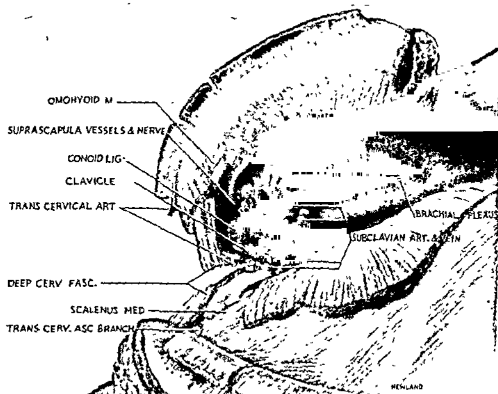


Fig. 59.—The brachial plexus has been divided; the subclavian artery and vein divided between ligatures; the omo-hyoid sectioned, and only the clavicle connects the upper extremity with the trunk.

AMPUTATIONS OF THE FOOT

Amputations of the toes.—Amputation of the terminal phalanx of a toe is frequently required on account of painful corns or painful nails in a deformed toe It is the most satisfactory operation for recurrent ingrowing toe-nail and for onychogryphosis, and is best carried out by a single plantar flap. A transverse dorsal incision is made immediately behind the nail, through a line which marks the level of the interphalangeal joint The plantar flap includes all the skin on the plantar aspect of the toe, except the extreme tip The phalanx is then enucleated and the flap sutured in position.

It is not advisable to perform *partial amputations* of the outer four

toes through the first interphalangeal joint, or through the first and second phalanges. The stump remaining is useless, and may be a nuisance. *Amputation through the metatarso-phalangeal joint* is often required; the best method is by lateral flaps. For the great toe, the flap taken from the inner side should be the larger, and the incision should be carried farther back on the dorsal than on the plantar surface, so that the scar lies on the dorsal surface and away from the margin of the foot. For the middle three toes the flaps should be equal, the incision again being carried farther back on the dorsal than on the plantar surface. The incisions should be carried right down to the bone, and the base of the first phalanx enucleated with a small-bladed scalpel.

Amputation of any single toe (including the great toe) leaves the remaining toes as useful parts of the foot. *Amputation of two toes* may leave the remaining toes useful, provided that they are mobile and under control, but when the second and third toes have to be amputated there is much tendency for the great and fourth and fifth toes to become deformed. When *three toes have to be amputated* it is usually better to sacrifice all. The metatarsal heads constitute one of the main bearing points of the foot and should be preserved at all costs.

Amputation at the tarso-metatarsal joints.—Lisfranc's operation, first described in 1815, is a disarticulation through the tarso-metatarsal joints, the end of the cuboid and cuneiforms being covered by a long plantar flap, which extends forwards to the line of the roots of the toes In Hey's modification, disarticulation of the second metatarsal bone is not performed, but this bone is sawn across. Either of these operations requires a very long flap, which is seldom available. The resultant stumps are not too unsatisfactory for weight-bearing and the only appliance required is an ordinary shoe with the toe stuffed with felt. These amputations are seldom performed.

Amputation through the tarsus.—Chopart's amputation through the midtarsal joint, first described in 1792, is covered with a plantar flap cut as far forward as the ball of the toe. This amputation requires a long flap, so that it is not often possible As ordinarily carried out, it has the great disadvantage of leaving the attachments of two strong tendons—the tendo Achillis and the tibialis posticus—both of them plantar flexors, and the latter an invertor of the foot. The peroneal muscles and extensors of the foot lose their distal attachments in this amputation, so that the stump, consisting of the astragalus and os c[illegible] acted into an equino-varus position, the [illegible] external aspect, and it is painful and diffi[illegible] t. The tendons can be re-attached in an attempt to prevent this contracture or a tenotomy of the tendo Achillis performed with arthrodesis of the sub-astragaloid joint, but although such procedures may improve, they do not entirely correct an unsatisfactory result.*

* We have seen several satisfactory cases of Chopart's amputation performed many years ago.

Amputation through the extreme distal part of the tibia and fibula (Syme's amputation).*—The classical amputation at the ankle is named after Syme; the bones are divided one eighth of an inch above the ankle joint and covered with a skin-flap taken from the posterior part of the heel. When this operation is successful it yields an excellent stump capable of complete end-bearing, so that the patient can jump out of bed and walk across his room in the morning without having to put on his artificial foot or use crutches. It has, however, certain drawbacks: the end of the stump is bulbous, and cannot

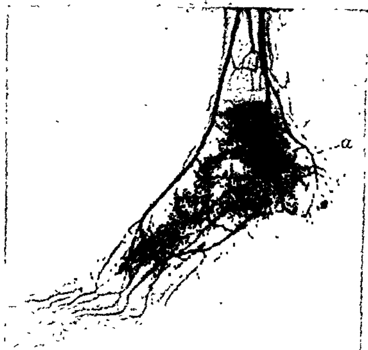


Fig. 60.—Radiogram of a foot with opaque injection in the arteries. Note the position of the artery of supply to the flap of a Syme's amputation

a, Calcaneo-plantar branch of the posterior tibial artery
(*From Treves, Surgical Applied Anatomy, Cassell*)

be slipped into a tapering socket, but must have made for it a leather socket which fastens with either a lace or a zip fastener. Moreover, the stump is so long that it does not leave sufficient clearance to allow the makers to fit an ordinary type of ankle joint in the artificial foot, and the necessity for the special type of socket and the external ankle joint may subject the end of the stump to friction, with the result that it may be rubbed sore Further, the operation has very frequently been carried out badly or on unsuitable cases, so that an unsound stump results.

For a period there existed at Roehampton a hostile attitude towards the Syme and Gritti-Stokes amputations, which seemed strange to the authors (G.G.-T. and A W J C.) who had enjoyed the privilege of seeing at the Veteran's Hospital at Toronto dozens and dozens of patients who had many years before been submitted to one or other

* Syme's description of the operation was published in 1843

of these operations with manifestly satisfactory and enduring results. The attitude at Roehampton has become less uncompromising of late.

In order to be a satisfactory end-bearing stump, Professor George Perkins from his great experience of amputation problems lays down these three dictates: (a) the whole of the bearing surface must consist of compact bone, (b) the deep tissues must adhere firmly to the cut surface of the bone, and (c) the skin over the end of the stump must be well-nourished and mobile, and also accustomed to bear weight. Perkins points out that one of the causes of failure in the case of the Syme and Gritti-Stokes has been an endeavour to placate the limb-fitters, whereby the saw-cut traversed the bone above the limit of the cancellous bone and " the bearing surface consisted ultimately of a ring of compact bone with nothing in its centre" (Perkins). A sufficiently wide surface of bone to distribute the pressure widely can only be found where the bone is cancellous, i.e. " near the articular surface and the nearer the better ".

Syme's amputation.—With the thumb and forefinger placed respectively over the two malleoli, an incision is made down to the inferior surface of the os calcis, just anterior to the tubercles of that bone, a plantar flap is now raised by forcible retraction by means of thumb and forefinger and the employment of a stout knife which *must be kept close to and hug the bone.* The tendo Achillis is sectioned and attention next directed towards the dorsal segment of the incision: this is carried across the dorsum of the foot at the level of the ankle joint, which is about half an inch (1 cm.) above the internal malleolus. The foot is now forcibly plantar-flexed, the tendons in front of the ankle with the anterior tibial artery and the anterior tibial and musculo-cutaneous nerves are divided, and the articulation is opened. The foot is then still further plantar-flexed and rotated inwards, the several portions of the external lateral ligament being thereby made tense and divided. Similarly, the foot is now externally rotated and abducted, and the tense internal lateral ligament divided, the greatest care being taken not to damage the posterior tibial artery and its terminal branches or the calcaneo-plantar artery which arises from the posterior tibial near its termination. A few touches with the knife sever the posterior capsule and the foot is removed.

The skin is retracted and the tibia and fibula are sewn across parallel to the long axis of the limb. Syme laid down that the level of section should be high enough to obtain the smallest possible diameter of bone surface and yet low enough to pass through a point where the bones are both in contact and held firmly together by the tibio-fibular ligaments. Syme himself suggested half an inch above the joint; but George Perkins directs that " unless a small portion of articular cartilage remains on the cut surface of the tibial shaft the section has been made too high "

The tendons are now pulled down and shortened; the nerves are divided as high as possible and the vessels secured. Deep sutures attach

the heel flap to the periosteum on the front of the tibia. The skin edges are co-opted and the flaps are held in position by means of Elastoplast. This strapping is retained until assurance is felt that the heel flap is firmly adherent to the bone—some three or four weeks.

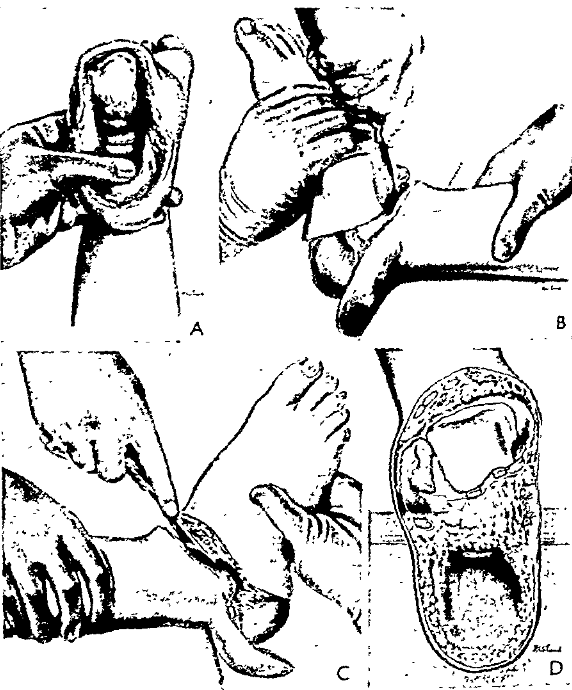
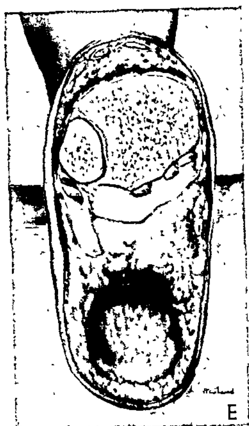
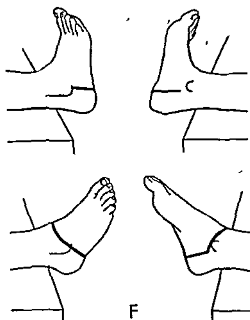


Fig 61.—Syme's amputation.

... portion of the os calcis the tendo Achillis divided at this ... uctures on the medial side of ... lateral aspect of the ankle ... fore removal with saw





Syme's amputation.

E, Removal of articular surface of the lower end of the tibia and the lateral malleolus. F, The stages of incision

AMPUTATIONS THROUGH THE LEG

Below knee amputation.—Older methods of fitting limbs, more particularly in relation to weight-bearing sites, have been revised: this is specially noticeable in limbs worn on the lower part of the leg. Formerly in a " below knee " prosthesis the transmission of the weight was chiefly through the lower part of the patella and the head of the tibia to the socket of the artificial limb, and the part of the stump below this area was merely a lever to transmit movement to the artificial leg. This seemed to indicate that the long stump had an advantage; but the taking of too much weight on the head of the tibia causes bursitis and the long stump deteriorates from loss of circulation, whilst the shape of the limb is ungainly owing to it having to be made to accommodate an unshapely long stump.

If a " below knee" amputation can be performed at *the distal end of the proximal third of the lower leg* it provides the ideal stump for the patient's comfort and for the general and continued health of the stump; a well designed and naturally proportioned artificial limb may be fitted satisfactorily for all concerned. This does not mean that shorter stumps cannot be fitted, since with the advances made of recent years some short stumps, previously considered to be unsuitable for a normal " below knee " limb, are now quite well fitted and comfortably

worn by the amputee. Reference to Fig. 62 will show the flexed short stump with a surgeon's or limb-fitter's index and second finger testing the length of the posterior part of the stump. If the stump can be flexed and exert a pull on the fingers it can be satisfactorily fitted. At one time such short stumps, and also those in which the knee joint was ankylosed at a right angle, were fitted with what is termed a "kneeling prosthesis". As a result of better post-operative treatment this type of limb is seldom required for recent cases: a stump containing only 1½ inches of tibia is sufficient to control an artificial limb, depending upon the general musculature and shape of the stump, but if there is less than 1½ inch an amputation above the knee is advised.

An amputation below the knee should have the scar situated on the lower posterior surface of the stump: this is obtained by means of a long anterior flap. The flap is marked out, with rounded corners, and reflected with an ordinary large scalpel, whilst the position and shape



Fig. 62.—Method of testing ability of a stump below knee by traction upon the flexed knee.

of the posterior flap can then be marked out and cut on the skin of the back of the calf, dividing everything down to the bones. The anterior flap being reflected, the muscles and interosseous membrane are divided, and the periosteum on the tibia and fibula stripped over an area of half an inch above the proposed level of bone section The fibula is divided an inch higher than the tibia, since an equal-length fibula can be a nuisance. Special mention is made regarding the length of the fibula in a later section dealing with amputations upon children. The anterior and posterior tibial and peroneal arteries and saphenous veins require ligature; the anterior and posterior and musculo-cutaneous nerves should be cut short. The lower front edge of the tibia should be cut away at about 45°, and any sharp end of the bones rounded off. After complete hæmostasis the flap is folded over and checked as to length and shape in order that it fits evenly over the end of the bones and cut musculature, being held by one or two temporary stitches, whilst any modification of the flap is carried out.

The Gritti-Stokes amputation.—This is a supracondylar amputation which was first described by Gritti in 1857 and later modified by Stokes who recommended that the femur should be sawn across from

one-half to three-quarters of an inch above the femoral condyles. The patella is retained and after removal of its articular surface is applied to the sawn end of the femur.

The operation is performed by taking a long flap from the front of the joint. With the knee extended the knife is entered above and

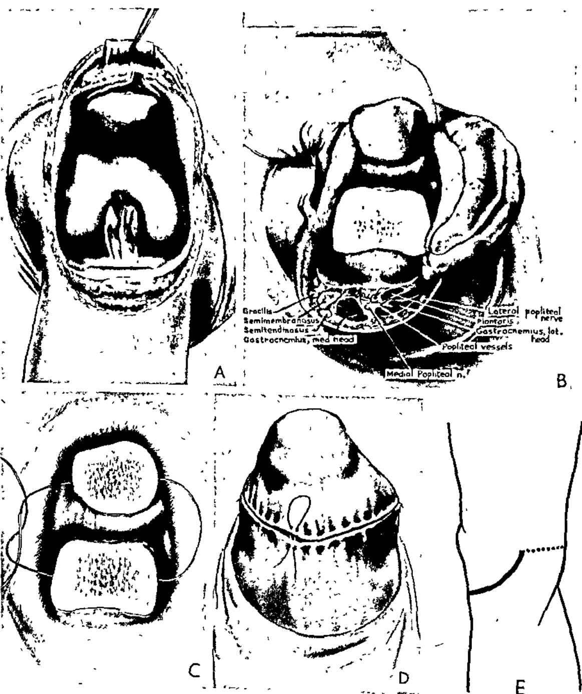


Fig. 63 —The Gritti-Stokes amputation.

behind the most prominent part of one condylė and carried in a curved line to the level of attachment of the patellar ligament to the tibial tubercle; it then passes upwards to a corresponding point on the opposite condyle. The incision should be carried down to bone and all the soft tissues freely divided; the ligamentum patellæ is raised from its attachment and reflected with the incised capsule. The posterior incision is a straight line joining the two points on the condyles and should be made cleanly through the deep fascia. The two cruciate ligaments are then divided and the hamstrings, nerves and vessels cut through with one sweep of the knife. The lower end of the femur is sawn through 1 inch above its most prominent part. The popliteal vessels and all small bleeding-points are secured and ligated. The articular surface is then removed from the patella, and this is best performed by holding the bone firmly in a swab and sawing off the surface with a small saw.

The patella is applied to the sawn end of the femur and secured in position by stainless steel wire, which is passed through two holes bored transversely through the patella and femur, the ends being then twisted together. The patellar ligament and capsule of the joint are now sutured with interrupted mattress catgut sutures to the deep fascia on the posterior aspect of the thigh. The skin is closed with interrupted overting nylon sutures. The wound is firmly strapped until the patella is firmly fused with the femur.*

Amputation through the thigh ("above knee" amputation).—A simple formula gives the correct length in every case. To provide the best surgical stump, and one that satisfies the limb-fitter, the amputation is best carried out at the *distal end of the middle third of the femur*, measuring from the tip of the greater trochanter to the articular surface of the lower end.

Reference has been made elsewhere to the undesirability of a scar across the end of the stump which will become adherent to the end of the truncated femur and therefore prevent free movement of the skin when the amputee is using the limb: amputations with equal anterior and posterior flaps are therefore undesirable. The preferable method is to make a larger anterior flap which can be folded over to meet the lower end of the posterior flap, permits free non-active movement of the skin and places the scar where it will not come into contact with the socket of the limb. The anterior flap is marked out and the skin cut and reflected with the subcutaneous tissue. This anterior flap is about three to four inches longer than the femur will be after it has been sawn across. The musculature can be divided down to the bone, carefully picking up all vessels and ligaturing them. On the posterior aspect the skin should be marked out where the anterior flap is expected to lie, a cutaneous flap being partially

reflected and the soft tissues cut down to the bone. The femoral artery and other vessels are divided and ligatured and the nerves are also sectioned.

The femur can now be cut through at the correct length, stripping the periosteum for about half an inch above the saw cut, at the same time rounding the sharp cut edge of the bone to allow the flap to move over the bone smoothly. The muscular attachments to the linea aspera should be divided off for at least an inch above the cut end of the bone. It has been suggested that the anterior and posterior musculature should be sutured together over the end of the bone owing to the tendency for the muscles to retract: they do not, however, appear to retract if they are cut at a slightly lower level than that of the bone section. The anterior flap may then be folded over and held with two or three temporary sutures to enable any modification being made to the line of final suturing in leaving a linear scar without puckering, infolded edges and "dog-ears".

It may not be possible to retain sufficient of the thigh to form what is described above as an "ideal stump". Short thigh stumps can be fitted quite satisfactorily provided there is sufficient length of stump to fit into the socket, which may have to be specially fitted in the artificial limb and the latter suspended from the body in a different manner, but nevertheless satisfactorily worn by an amputee. The great difficulty in the fitting of short stumps is the marked tendency of the stump itself to be always flexed owing to the loss of the musculature which controls extension. Stumps measuring only four inches from the tip of the great trochanter to the end of the stump may be fitted with a modified form of the ordinary "above knee" limb, but if there is less than four inches it may be necessary to supply the amputee with what is termed a "tilting-table" limb, the socket of which is somewhat like half a cup, fitting around the pelvis on the amputation side and in which the amputee sits, whether he is walking or sitting.

The fitting of this type of limb is much more comfortable to the amputee, and the limb-fitter is greatly assisted if the head of the femur and the great trochanter can be left; the stump will be flexed always and the prominence of the great trochanter prevents the socket from falling off the body. With this type of limb, as indeed with all "above knee" limbs, one should avoid any scar tissue in the region of the ischial tuberosity and on the under side of the stump where all weight-bearing must be taken.

AMPUTATION AT THE HIP

Disarticulation at the hip joint.—Disarticulation at the hip joint may be indicated in injuries involving severe damage to the femur high up in its shaft; in extensive necrosis of the femur; in certain cases of tuberculous disease of the hip joint with extensive suppuration and lardaceous disease; and in sarcoma of the femur. It is an operation which necessarily involves considerable shock; by adopting a method in which the femoral vessels are ligatured early the loss of blood can be

reduced to a minimum. The operation of choice is that in which most of the gluteal and other muscles are removed and a smooth and compact stump is left (Fig. 65): those methods which leave a loose, *mobile stump make it very difficult to fit a suitable artificial limb.*

The classical amputations were formerly the Furneaux-Jordan method and the amputation by a racket-shaped incision with the vertical part in front. Neither of these is satisfactory from the point of fitting an artificial limb, because the flap does not fit down sufficiently closely to leave a neat stump without redundant tissue. The best method is that advised by FitzMaurice Kelly,* in which the flap is taken from behind and the periarticular muscles are removed almost entirely.

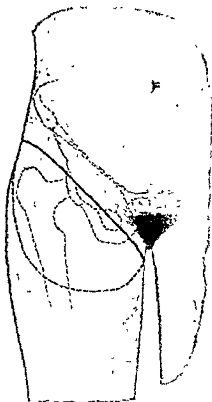


Fig. 64.—Amputation through hip joint by posterior flap with preliminary ligature of femoral vessels through anterior incision.

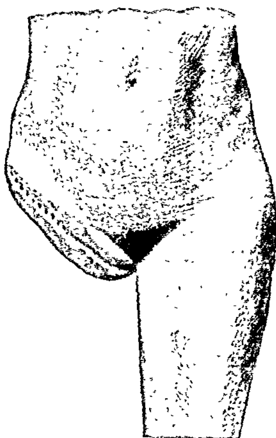


Fig. 65.—Amputation through hip joint, showing flat stump left when single posterior flap is used.

Amputation at the hip joint by a posterior flap. (Figs. 64, 65).—An anterior incision is made through the skin, starting over the adductors just below the inner end of the fold of the groin, and extending upwards and outwards parallel with Poupart's ligament to above fee great trochanter. This incision is deepened until the common femoral vessels are found, and they are ligatured and divided between the ligatures, the femoral nerve is at the same time divided. A

* This method is particularly valuable in operations for malignant disease

posterior flap is marked out, sufficient in length to cover the stump without tension. Its length at the maximum is equal to the antero-posterior diameter of the limb at the level of the hip joint. This flap is reflected upwards as a skin-flap as far as the tuberosity of the ischium, the sciatic notch, and nearly as far as the crest of the ilium. The amputation is then completed from the front, all the muscles being divided close up to the pelvis, and vessels ligatured as they are met with. The great sciatic, small sciatic, obturator and gluteal nerves are divided close to their exits from the pelvis.

In amputations at the hip joint two methods of dealing with the femur may be adopted: (*a*) the neck may be divided close up to the head, leaving the head in the acetabulum or, (*b*) the hip joint having



Fig. 66.—Patient on opposite side to lesion, but turned slightly on to his back; position maintained by support against lower ribs and dorsal spine. Upper and posterior parts of incision for "hindquarter" amputation.
(Figs 66–71 are reproduced with permission from Brit J Surg)

been opened from the front, the head is forced out of the socket and the femur removed entirely. The former method is only suitable for amputations under aseptic conditions and when the head of the femur is not suspect; it should not be adopted in amputation for sarcoma of the femur: its advantage is that it leaves a rather better surface to the stump. Complete disarticulation is necessary in amputation for sarcoma or tuberculous disease of the hip joint, for cases of other infections of the hip, and for injuries involving the head of the femur. If the head of the femur is left, care must be taken that no muscle remains in contact with it, for if a muscle becomes adherent to the cut bone the latter may subsequently become disarticulated from the acetabulum. The wound may be sutured with drainage, redundant skin being cut away if necessary. The remaining stump takes an artificial limb well, the weight being borne chiefly by pressure on the tuberosity of the ischium, but distributed to a slighter extent over the whole outer surface of the pelvis.

Interinnomino-abdominal amputation ("hindquarter" amputation).—Pre-operative management of this amputation has kept in step with modern trends in the preparation of patients for major operations. Instruction is given in breathing exercises, and penicillin and streptomycin therapy is started the day preceding operation. In view of the massive transfusion which on occasion has been necessary

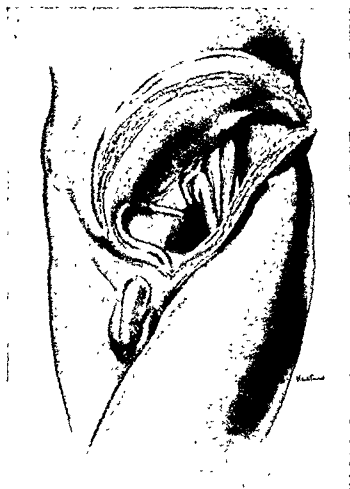


Fig. 67.—Exposure of the bifurcation of the common iliac artery by an incision cutting through lateral and anterior abdominal muscles. The ureter is being drawn medially by the retracted parietal peritoneum.

it has become customary for the authors to hold ten pints of matched blood in reserve and to c[illegible] routine

Premedication is with [illegible]

of choice is thiopentone, [illegible] author (G G.-T) on the advisability of unilateral spinal anæsthesia to block the effects of section of major nerves of the affected limb and of the inevitably carnivorous traction on the limb which immediately precedes its final severance from the body.

After being anæsthetized the patient is placed on the operating table lying on the side opposite to the lesion and is turned slightly on

to the back. This position is maintained by a support against the lower ribs and dorsal spine, well clear of the iliac crest, and by an assistant who stands at the far end of the operating table on the same side as the surgeon and holds the limb until its complete removal from the body. The uppermost arm is supported on a rest such as is used for nephrectomy, and into its veins are inserted the needles of two

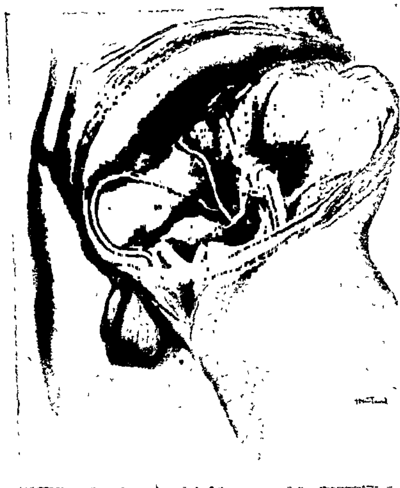


Fig 68.—The common iliac artery has been divided between ligatures; exposure of common iliac and ilio-lumbar veins, *which is facilitated* by division of the ilio-psoas muscle at this stage. The *symphysis pubis* is now divided with a stout knife, perhaps reinforced with a chisel. Monro's Ridge on the posterior aspect of the *symphysis* forms a valuable guide to the joint.

separate pieces of drip transfusion apparatus. A sheet of oiled silk is stitched to cover and conceal the anus and a catheter passed; formerly the latter was tied in, but a Foley catheter is now employed. Finally an Esmarch bandage is applied to an appropriate level on the limb to be amputated to conserve the blood volume; the skin is widely prepared with cetavlon and tincture of iodine, and the patient draped.

The incision usually practised consists of two parts, anterior and posterior. The *anterior* is made initially and lies immediately above the inguinal ligament (Poupart's ligament), being prolonged upwards

and backwards just above the iliac crest to an extent varying with the point at which it is intended to divide the pelvic girdle; the incision is then carried downwards across the pubic tubercle into the crease between the adductor region of the thigh and the perineum. The *posterior* part of the skin incision is made later in the operation, but is conveniently marked out with "Bonney's blue" at the commencement; it runs from the upper and posterior part of the first incision



Fig. 69—Posterior incision through gluteal muscles for exposure of the sciatic notch preparatory to section of the iliac bone through dorsum ilii.

downwards, with a considerable convexity forwards in front of the great trochanter, subsequently winding around the posterior aspect of the upper thigh to meet the lower end of the anterior incision in the vicinity of the ischial tuberosity.

The antero-superior incision is deepened through the abdominal musculature above the iliac crest and in the groin, and the peritoneum is pushed medially from the iliac fossa and pelvic brim so as to ascertain at the earliest moment the operability of the malignant tumour. The spermatic cord is next mobilized and displaced medially; the deep epigastric vessels are secured; the pubic insertion of the ipsilateral

rectus abdominis is divided, exposing the symphysis pubis; the bladder is separated from the back of this bone and protected by a pad; the symphysis is divided with a knife; sometimes its complete dislocation at a later stage may require a little levering with a chisel. A ridge on the *posterior aspect* of the pubic bone in the *median plane*



Fig. 70 —Posterior exposure of posterior iliac spine region, and of the posterior limit of sciatic notch for section of pelvic girdle through sacro-iliac articulation.

(Monro's Ridge) often provides a valuable guide to the exact position of the symphysis

The external iliac artery is identified and followed upwards, peritoneum and ureter being pushed medially until the common iliac vessels are exposed. The psoas is conveniently sectioned at this stage and the iliolumbar vessels demonstrated, thus facilitating the exposure of the common iliac vessels The common iliac artery is ligated and divided, the iliolumbar vein or veins are secured, and the common iliac vein mobilized, ligated and divided. The whole lower iliac vascular pedicle is then pushed gently downwards until a finger can be introduced lateral to and above it into the apex of the sciatic notch

The patient is now rolled very gently into the full lateral position and the posterior skin-flap cut. Where the ilium is not involved, the gluteus maximus is also in part reflected in the skin-flap, and the gluteus medius divided so as to expose the apex of the sciatic notch posteriorly; a pair of cholecystectomy forceps is then thrust through the notch from behind, forwards and upwards into the pelvis, emerging above and behind the distal segment of the divided vascular pedicle; by means of the forceps a Gigli saw is drawn through the notch and



Fig. 71A.—Antero-posterior view of bony pelvis, showing line and direction of section with Gigli saw. A A′ = sacro-iliac section. B B′ = section through dorsum ilii.

employed to divide the ilium upwards and outwards to the junction of the middle and posterior thirds of the iliac crest.

The pelvis can now be opened out, the patient being rolled dorsalwards; the pelvic viscera are pushed medially, the crus penis and urogenital diaphragm are detached from the pubis, and the levator ani is divided. The laterally directed branches springing from the internal iliac vessels, comprising the obturator, superior and inferior gluteal, and internal pudendal branches, are secured, the sacrotuberous and sacrospinous ligaments are divided and the amputation is completed by severing the pyriformis and the sciatic nerve. Bleeding points are secured, and the wound is closed by suturing the gluteus maximus to the anterior abdominal musculature and coaptating the skin edges.

Recent developments in the technique of the operation have concerned the division of the posterior segment of the pelvic girdle, since

in about 40 per cent of one of the authors' (G.G.-T.) recent cases it has been necessary to section the girdle through the sacro-iliac joint rather than more laterally through the ilium. The operative mortality for sacro-iliac disarticulation in this series has not conspicuously differed from that for iliac section, but mortality figures alone do not reflect a true comparison of the severity of the two procedures, and sacro-iliac disarticulation is unquestionably a more difficult and anxious operation.

The chief hazard encountered in the division of the posterior segment of the pelvic girdle is hæmorrhage from the iliac vessels and their

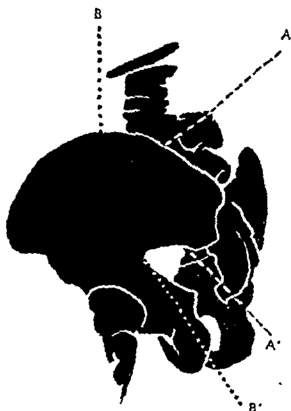


Fig 71B.—Lateral view of bony pelvis showing line and direction of section with Gigli saw. A A' = sacro-iliac section. B B' = section through dorsum ilii.

immediate branches; the thin-walled iliac veins in particular are easily damaged. The danger is best avoided by observing the following points of technique.—

(1) Elective ligation of the common iliac vessels.
(2) Division of the symphysis pubis prior to embarking on the posterior section of the girdle.
(3) Use of a Gigli saw and avoidance of the chisel.

Ligation of the common iliac vessels is of course obligatory where sacro-iliac disarticulation is contemplated, and convenient where iliac section is proposed. In the latter group separate ligation of the external iliac vessels and of the posterior division of the internal iliac

vessels is possible and was formerly advocated by us, but this technique is unnecessarily complicated and would seem to confer no advantage, since common iliac ligation has provided more certain hæmostasis when the gluteal flap has been cut, and has not resulted in ischæmia of the pelvic viscera or in any significant impairment of vitality of the posterior skin-flap. In cases where the posterior flap has sloughed subsequent to operation, the determining factor has been rather that the flap has had to be cut thin on account of posterior extension of the growth on to the dorsum ilii, or because the tumour has already been hopefully but unavailingly irradiated.

Certain precautions have been found essential for sure and satisfactory common iliac ligation: the psoas is first divided transversely opposite the common iliac vessels, which are then approached from the lateral aspect with much greater ease. After ligation and division of the common iliac artery, it is imperative next to *secure the iliolumbar vein or veins,* which drain into the common iliac vein; once this is accomplished, the common iliac vein is readily mobilized and encircled with ligatures carried on aneurysm needles. Unless the iliolumbar vein is secured, this short vessel tethers the common iliac vein to the pelvic brim and is very easily torn from the main vein if inadvertent and untimely efforts are made to ligate the latter first; the hæmorrhage which results is extremely difficult to control and may greatly hamper ligation of the main vein.

Division of the symphysis pubis should be completed before any attempt is made to divide the posterior segment of the pelvic girdle. In the course of the latter procedure, even when carried out with a Gigli saw, some laceration of the superior gluteal veins is almost inevitable, and although the iliac vessels have already been ligated, fairly brisk hæmorrhage may take place. If the symphysis has already been divided, the whole pelvis can usually be opened out like an oyster shell as soon as the posterior bone section is completed, and hæmorrhage is readily controlled by simple pressure of the swabs placed over the pelvic viscera, no further hæmostatic steps being necessary until the amputation has been completed. On the other hand, if the pelvis cannot be opened out because of postponed division of the symphysis, the hæmorrhage following posterior bone section is difficult to control and a considerable volume of blood may be lost before the symphysis can be divided and separated

For section of the posterior segment of the pelvic girdle no instrument is more safe or more efficient than the *Gigli saw*; other forms of saw cannot be conveniently introduced, while chisels easily slip and may cause disastrous damage to the adjacent iliac veins. The Gigli saw can be introduced satisfactorily even in cases where exuberant growth overhangs and obscures the sacro-iliac joint anteriorly, and can even be made to cut through the ala of the sacrum with safety

Where the ilium is not itself involved by growth and section of the dorsum ilii suffices, the Gigli saw is easily introduced after reflection of the gluteal flap and division of the gluteus medius down to the

bone on a line from the junction of the middle and posterior thirds of the iliac crest to the angle of the sciatic notch.

Where sacro-iliac section with complete removal of the ilium is required, the posterior flap must be reflected farther back so as to expose the posterior iliac spines and the sheath of the erector spinæ; the flap consists of skin and subcutaneous tissue only, the gluteus maximus being left undisturbed. The erector spinæ aponeurosis is divided immediately behind the posterior iliac spines and gives a clear indication of the required line of section. The incision is continued in its lower part into the origin of the gluteus maximus and splits the muscle in the line of its fibres immediately below the posterior inferior iliac spine. The lower end of the Gigli saw is introduced in a manner similar to that already described, except that the forceps are thrust through the sciatic notch as close to the margin of the sacrum and sacro-tuberous ligament as possible, rather than at the apex of the notch.

Superiorly, the iliac crest is cleared completely by detaching the quadratus lumborum and erector spinæ: the upper end of the Gigli can now be brought over and round, so that the saw lies snugly in the iliolumbar angle and across the anterior aspect of the sacro-iliac joint, dividing the iliolumbar ligaments and the pelvic girdle in the plane of the sacro-iliac joint.

Occasionally the upward spread of a massive neoplasm such as a chondrosarcoma of the ilium has obliterated the whole space between ribs and iliac crest. Sacro-iliac section can still be achieved, but instead of the iliac crest and iliolumbar angle being cleared above as a preliminary to the saw cut, a modified Steinmann pin is thrust from before backwards through the interspace between fourth and fifth lumbar transverse processes; the upper end of the saw is attached to the butt end of the pin, and is drawn through to the back, so that once more the saw lies across the front of the sacro-iliac joint, its two ends projecting posteriorly.

POST-OPERATIVE TREATMENT AND REHABILITATION

The post-operative care of every amputation stump and of the amputee is as important as the main surgery—indeed it is better to consider the whole period before an artificial limb is satisfactorily fitted as one continuous treatment under the supervision of surgeons and physiotherapists. Formerly it was the practice to allow the patient's stump to be placed or supported on a soft pillow immediately upon return to bed in the ward and to continue this comfort for several days, even until the stitches were removed This practice has been found detrimental: the pillow or other support flexes the stump at the hip joint, and also at the knee joint in " below knee " amputations, and the stump having been allowed to remain passively in this manner for some days the flexion persists for some considerable time. An "above knee" stump should have a towel placed over the extended stump and held firmly in position by sand bags placed on each side of the stump. A cradle may be placed over both limbs which not only











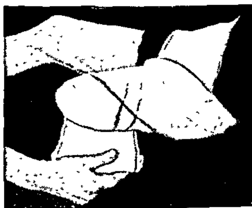






Fig. 72.—Correct method of bandaging an "above knee" stump.

permits periodic inspection for hæmorrhage, but also ensures that there is no movement of the stump from full extension. A "below knee" stump is placed in full extension with a padded splint underneath and bandaged around the thigh and below the knee: covering towel and sand bags are unnecessary in this case, because the weight of the amputated limb will restrain any tendency of movement, except at the hip joint where it is an advantage.

This restriction of movement—indeed of any movement by the stump—is removed completely after 24 hours, when gradually increasing active movement of all the joints above the level of amputation is supervised by the physiotherapist. If a stump is bandaged correctly after the operation, these gradually increasing movements will not disturb the bandages and stitches or delay healing, but will assist and reduce the tendency to œdema and loss of tonicity in the whole musculature.

Bandaging of amputation stumps.—All amputation stumps need to be bandaged night and day from the time of amputation with some form of crêpe bandage, and the bandaging should be continued for some six months or more after supply of the artificial limb, whenever the limb is not being worn. If this injunction is neglected, there is always a tendency for the stump to swell or become mis-shapen from œdema. The ordinary roller cotton bandages requiring very frequent attention and re-application are not satisfactory; a crêpe bandage, if applied correctly, remains undisturbed and gives proper support to any stump, even while "stump" exercises are carried out. The method of application of the bandage is very similar for all stumps. (Fig. 72) A correct width of bandage must be used for each particular stump, an "above knee" stump requires a 4 inch single length bandage, but a 3 inch wide one of single length is suitable for the "above" and the "below elbow" stump. All bandages should be rolled tightly each time before being applied. The appropriate crêpe bandages should be re-applied two or even three times a day to correct any looseness which may develop.

Exercises.—The amputation stump should have gradually increasing exercise from the day after amputation in order to maintain the joints and musculature above the amputation level in a normal condition

The "*above knee*" amputee should begin by raising and abducting the stump at the hip joint slowly and through an increasing range of movement When the sutures are removed and the scar is consolidated, a further exercise should be continued daily (Fig. 73) until the prosthesis is supplied, the main feature of which is that the muscles round the hip joint are exercised in lifting gradually increasing weights from about 7 lbs to 14 lbs : the bandage is removed, but reapplied after each period of exercise. Flexor and extensor action is trained, when the patient stands facing the apparatus used: the abductor and adductor muscles are exercised when the patient stands sideways. In a



Fig. 73.—Exercises to prevent wasting of the muscles round the hip joint.

training school special apparatus may be set up, but at home a pulley may be fixed to the chair as shown (Fig. 78), or the cord may pass over a door handle with sand bags, a flat iron, etc. being used as the weight: a handkerchief around the stump with the cord attached constitutes a quite serviceable unit.

The "*below knee*" *stump* may be trained for its proper use in the control of a prosthesis by the patient kneeling on both knees on a cushion and learning to balance himself in the kneeling position, while the knee joints and the hip joints are flexed and extended: this is more or less equivalent to sitting and rising in a kneeling position. The amputee should also stand erect on the normal leg and move both the knee and hip joint of the amputated limb in all directions, maintaining his own balance.

Arm amputees, both above and below elbow, can commence movements of the stump and of the joints above the amputation-site on the day after the operation, even without any apparatus. It is imperative that the fullest movement of the shoulder joint in all directions be obtained as soon as possible, and maintained. A right-handed right "below elbow" amputee should have a pencil incorporated in the lower part of the bandage to allow him to write and sketch as soon as the stitches are removed, the method being reversed if the patient is left handed and undergoes a left-sided amputation. On no account should a patient be taught to write with the opposite hand to that which he has been accustomed to use previously.

In Britain, where the artificial limb is supplied to the patient under the ægis of the National Health Service, he is required to attend a training centre of the Ministry of Health, which Ministry now provides all requisite prostheses and maintains them in proper condition under the National Health Scheme

Perhaps the most important consideration in the care of an amputation stump is that of personal hygiene. All stumps should be carefully washed with a good quality soap every day, preferably a soda-free soap which does not require to be "dried off": the scar tissue itself should be treated with the greatest gentleness. Surgical spirit should be lightly applied to remove all remaining moisture and the area of the scar finally dusted with talc powder of good quality.

A clean stump sock each day should be worn next the skin. Stump socks will shrink unless washed correctly and may not only constrict the stump, but become too short, thereby allowing the skin to become abraded by contact with the top of the metal socket or leather corset of the prosthesis Similarly the crêpe bandages employed to reduce œdema and prevent the stump swelling at night should be washed regularly

An amputee begins a new phase in life immediately after amputation, but he should be able to leave hospital with full assurance that even if it is not possible for him to resume his previous employment an equally remunerative and interesting vocation can be found for him The

patient himself, however, must co-operate wholeheartedly from the time of operation until he is fit to return to work.

For an "above knee" amputee, the whole limb except the foot which is made of wood, is made from various forms of aluminium. Some parts are castings, others are made from sheet metal specially shaped to resemble the appearance of a normal leg and to take the strains and stresses imposed upon the limb whilst it is worn.

The metal fitments at the level of the hip incorporate various joints to allow the free movement of the limb controlled by the stump, such as may be required in walking or sitting and similar in effect to that of the normal hip joint.



Fig. 74A.—The modern artificial limb for the patient with amputation through the hip joint, showing the socket with padded area on which the ischial tuberosity rests and the limb locked in the standing position.

The means of suspension from the waist by a pelvic leather belt is shown in Fig. 74A.

For female patients a slightly different form of suspension is used. This takes the form of a shaped waist belt which has small straps connecting to roller cords passing under rollers on the side of the limb, and prevents any noticeable disfigurement under ladies' clothing.

Both types of limb have an articulated knee joint for flexion and extension in walking, the freedom of the movement being controlled by a braking mechanism in the joint itself. The small wheel just above the knee can be rotated to adjust this brake without disturbing any clothing and can be operated to adjust the swing of the leg quite easily. The foot has a flexor and extensor action which operates automatically as the patient walks.

These limbs are controlled during walking by the stump which normally measures some 10 to 12 inches in length A longer stump is not required to give extra leverage or swing, and there are many patients with much shorter stumps who wear this type quite satisfactorily. With a very short stump a modification of the suspension may be necessary for a male patient. Some limbs have cords passing through the mechanical knee attached to suspenders, which pass over the shoulders to enable the lower part of the leg to be controlled by the

lift of the shoulders in walking; these are not adaptable to women's artificial limbs.

Some patients have a stump so short that it is not possible to fit a socket; others have a complete disarticulation of the hip joint and with the whole of the femur removed there can be no stump; Fig. 74A illustrates the prosthesis which is fitted in these cases, the part fitting around the lower part of the body being the socket; the waist belt is of varying design according to the sex of the patient. The hip joint is duplicated in this limb, as is seen in Fig. 74B. The outer hip joint has a lock which maintains the thigh portion in full extension whilst standing or walking: the lock is released by pressure on the small knob at the side to allow the patient to sit as indicated in Fig. 74B; when the patient stands, the lock automatically comes into action. The same braking device can be fitted to the knee joint if required; some male patients are given the shoulder control of the lower part of the leg as described above.

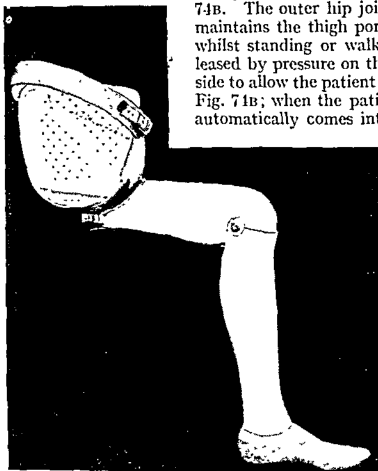


Fig. 74B.—The same limb with hip and knee flexed for sitting.

Each of the artificial limbs can have a locking device for the knee joint so that the whole leg is in full extension when the patient has to "stand" at work. With a normal length of stump this is not necessary, the extension being maintained solely by the stump.

For the "below knee" amputation the socket is made of wood which is considered to be more suitable for many patients especially

ngth. The

the thigh

supports the weight of the body, either walking or standing. The corset is made of leather or some plastic, which is blocked to the shape of the thigh and laced up in front.

The knee joint works on one centre of movement, but it can be replaced by a polycentric form of knee joint, more closely resembling

the action of the normal knee in which there is a sliding action of the condyles of the femur upon the head of the tibia; the greater range of flexion of the lower part of the artificial limb thus obtained enables the wearer to place his foot farther under a seat when sitting at table or when travelling in public vehicles: cycling is also made easier.

The ideal length of a below knee amputation is five inches to five-and-a-half inches, and with this measurement and also with shorter



Fig. 75.—A, an artificial limb for "below knee" amputation. B, another pattern. note the brim for the ischial tuberosity.

stumps it may seem preferable to fit the type of limb illustrated in Fig. 75. The lower part or "shin" is made of aluminium especially shaped to resemble the natural calf and leg· there is a metal ankle joint with roller bearings facilitating the movement of the wooden foot in walking. The stump fits into a leather socket made upon a cast previously taken of the stump itself, the corset is made to conform to

the shape of the thigh and to assist in taking the weight of the body while the limb is worn.

Both types of limb are suspended by a fabric brace over the shoulders with an elastic portion at the end of the brace in front and behind to prevent the pull of the brace being too rigid on the shoulder. The braces are replaced by a waist-belt for female patients to which the elastic supports are similarly fitted. A waist-belt can also be fitted for male patients.

It will be noticed that both types of limb for the " below knee " amputation have the corset shaped in its upper part exactly like the upper rim (" brim ") of the sockets of the artificial limbs for " above knee " amputations. The reason for this is to allow the body weight to be taken by the ischial tuberosity resting on the " brim " when the patient is walking or standing.

Any pressure or friction on or around the knee joint causes a bursitis or corns with consequent swelling and much pain. With the modern type of corset, which takes the weight of the body by the ischial tuberosity and in some measure by the whole length of the shaped corset, the incidence of bursitis is greatly lessened in older cases and entirely prevented in the case of recent amputees. With women it is not wholly possible to take the full bearing on the ischium, and a greater supporting effect is obtained by the closely fitting shaped corset.

Some male amputees also, who are mainly employed in sedentary work, have the corset fitted a little below the ischium for greater ease when in the sitting position.

Shrinkage of an " above knee " stump may cause the ischial tuberosity to slip inside the brim of the socket with the result that the pubic bone rests on the socket in the adductor region. The slight up and down movement of the stump in the socket, so-called piston action, causes friction in the area and often inflammation of the skin. As a temporary measure an extra sock may be of assistance.

The modern artificial arm.—Arm amputees are unquestionably more disabled than those who have lost a leg: the very fine movements of the hand and of the arm, which are required in some professions and trades, even in the heavier work of various trades, are the result of long education of the brain from early childhood, an education which can never be said to be completed.

However, the modern artificial arm with its very extensive range of appliances for various occupations is a very serviceable replacement of the normal arm and by no means a mere dress appliance to fill an empty sleeve The ability with which an arm amputee can use this modern prosthesis depends entirely upon the rapid re-education of the stump after amputation, together with the will of the individual to overcome his temporary disability; but greater perseverance and a longer period of training are necessary than in the case of leg amputees.

Many who have undergone amputation for some congenital deformity of the upper extremity are conscious that the artificial limb

found from long experience of all classes of amputees that *detachable hands serve a more useful purpose.* a very simple release mechanism at the wrist detaches the hand in an instant: any tool or appliance on which *an adaptor* is fitted can replace the hand, either at the wrist joint, or just below the elbow, as in some upper arm types of limb

There are numerous appliances which amputees can use with exceptional skill, such as: a knife, spoon and fork, a telephone appliance which can be used by stump and shoulder control, a spade grip, a toolholder for men and a knitting needle holder for women

Any professional man, craftsman, housewife, skilled or unskilled worker may have an adaptor fitted to every tool they wish to use, so that the latter can be attached to an artificial arm. A little practice overcomes their disability to a great extent.

A special "writing" hand.—It is rather difficult to hold a pen or pencil in a natural manner with the ordinary form of Certalmid hand, and possibly this fact has deterred some wearers of artificial arms from using the normal side for writing as they did before amputation. A rubber hand overcomes the difficulty of holding the pen or pencil, but it is rather heavy and, with gloves which are necessarily worn for the sake of appearance, or even without the gloves, the artificial hand cannot glide smoothly over the writing surface.

A modified form of the light Certalmid hand enables the pencil to be held between the first and second fingers quite rigidly: very little alteration is required in the manufacture of the hand for this space to be enlarged, and the third and fourth fingers, being flexed a little more, rest on the writing surface and the hand can still be used for carrying articles. Pencil and pen adaptors are also available, but these do not look natural, and it is disconcerting for an amputee to have to use them in public.

AMPUTATIONS IN CHILDREN

Amputation surgery in children needs some special consideration. Apart from severe accidental injury and infrequent pathological conditions demanding ruthless ablation, there are some congenital deformities that are better treated by amputation and fitment of a prosthesis.

The child amputee proves a very apt and able pupil in the use of an artificial limb, many cases of amputation of the lower limb learn to walk almost naturally and the arm amputees to use the artificial arm with excellent control It is the practice nowadays to fit children with prostheses at a much earlier age than a few years ago; young children of fifteen and eighteen months have in fact been furnished with artificial legs, although the issue of artificial arms is best postponed to about four or five years of age. Formerly these mutilés were sent to special schools where they were segregated from children of the same age with no disability, and were thus deprived of what should be a natural life, and they suffered mentally. All children who have undergone a limb amputation are given a duplicate prosthesis which

allows wear and tear to be made good, recurrent adjustment of the limb for length during the years of growth and, an important factor, the replacement of either artificial limb as it becomes irreparable from the child outgrowing it or from extreme damage: a child makes more use of the artificial limb and imposes greater strains upon it than an adult! All children are now fitted with correctly designed limbs, whereas at one time temporary pylons for walking were used and few arms were supplied. Children's crutches also require periodic renewal.

In children, growth continues in certain bones after amputation: in the leg growth takes place mainly at the distal end of the femur and the proximal ends of the tibia and fibula; whereas in the arm growth occurs at the proximal end of the humerus and the distal ends of the radius and ulna.

Remembering the desired length for a " below knee " amputation in an adult and that the bones of the lower leg do grow to some extent, an effort should be made to obtain as early as possible the ideal length of stump below the knee, as in the case of an adult (5½ inches). If 3 to 4 inches of tibia can be left in a child, the extra inch or so of growth will give the ideal length later. The fibula grows more than the tibia, cases having been seen where the fibula has grown and stretched the covering skin, and it should be cut at least one inch shorter than the tibia; the head of the fibula should never be removed.

In the " above knee " amputation in a child, it should be recalled that the femur will not undergo much, if any, increase in length, and one should try to provide a stump at least 8 inches measured from the tip of the great trochanter, which will allow a limb to be worn throughout life. A " through knee " amputation has been suggested for children to be followed later by a re-amputation to give an ideal length. This requires, however, a special " through knee " prosthesis to be fitted during the period of waiting for the femur to grow to its full length, which the child becomes accustomed to use; then after re-amputation he is given a different type of limb and has to start learning afresh to walk with this new limb. Furthermore, the re-amputation may be required during the important years of schooling or commencing work, with consequent loss of time. Unfortunately, some children thus treated never have the necessary re-amputation and lose the advantage of a correct prosthesis.

If a very high amputation of the femur is necessary, the temptation to remove the whole of the femur should be resisted where possible: the head of the femur is invaluable in the fitting of the special prosthesis required for very short stumps.

Growth of the humerus taking place at the proximal end appears to be retarded after amputation, although in some cases observed over a number of years a growth of 1–1½ inches has been recorded. Transcondylar amputation and disarticulation at the elbow should be avoided in children. If there has been severe trauma to the humerus and only a short stump is obtainable, sufficient length should be left below the axilla to fit a prosthesis, as in the case of an adult. Amputation

stumps below the elbow do not grow in length and a final length of stump should be obtained, and as in adults a stump too long or too short should be avoided.

Of course all joints above the amputation site have gradually increasing exercises and movements from 24 hours after the amputation, in order to obtain full range of movement when the sutures are removed. It is disconcerting to be confronted with juvenile arm amputees to whom these exercises have not been given, with the result that shoulder movement is much restricted and in some the stump cannot be raised above the shoulder.

A child amputee needs constant attention to the bandaging of the stump during the whole time from operation to the fitting of the prosthesis. In small children a bandage only 4 inches wide should be used for "above knee" amputations, a 3 inch bandage for "below knee" cases and possibly a 2 or 2½ inch bandage for the arm. Older children will of course require wider bandages.

THE ELDERLY AMPUTEE AND AMPUTATION SURGERY IN VASCULAR DISEASE

Amputation of a limb may be necessary as a result of vascular disease which has either produced gangrene threatening the life of the individual or pain of such severity that removal of the extremity is the only remedy. The arm is rarely affected in this way and the problem really involves only the lower limb.

The objects of the operation are to remove the avascular limb and to provide a healed stump to which a useful prosthesis may be fitted. It is important to have a sound knowledge of the disease process and of the existing circulation before any decision is made concerning the site of amputation, since it should always be the aim to amputate at as low a level as possible. There are several ways in which an appreciation of the existing circulation may be obtained, including oscillometry, arteriography, plethysmography, reactive hyperæmia and skin temperature tests.

The value of a sympathectomy should also be considered as a preliminary operation. There is no doubt that this procedure improves the circulation to the skin and subcutaneous tissues and assists in attaining maximum collateral circulation; it also provides a dry, warm skin which is less prone to harbour pathogenic organisms likely to provide a source of infection The objection to performing a sympathectomy as a routine prior to amputation is that it involves two operations instead of one, and that the majority of patients are elderly. Age in itself, however, should be no bar to the procedure, since elderly people withstand the operation well, and if sympathectomy is likely to permit a low amputation, it should most certainly be performed because of the great advantages which result

Control of sepsis in the limb segment affected is essential: infection is always present to a greater or lesser extent in cases of gangrene and, if treated satisfactorily in the early stages, should rarely make

amputation necessary as an emergency procedure. Control of infection may involve preliminary local drainage of pus and the use of suitable antibiotics. When the elected amputation is performed, strict aseptic technique is essential, since breakdown of the wound is more commonly due to infection than to inadequate circulation to the skin flaps. Coupled with the control of infection is the maintenance of adequate hæmoglobin levels in the blood, since chronic infection is a common cause of anæmia; furthermore, some degree of anæmia is often encountered in the aged as a result of malnutrition.

The vascular diseases which may lead to amputation are as follows:—

(1) Trauma to the vessels.
(2) Thrombo-angiitis obliterans. (Buerger's disease.)
(3) Arteriosclerosis resulting in gangrene or severe rest pain.
(4) Embolism.
(5) Deep venous thrombosis or incompetence resulting in chronic ulceration.
(6) Gangrene as a result of infection or in conjunction with diabetic disease.
(7) Raynaud's disease and allied conditions.
(8) Arterio-venous fistulæ.

1. **Trauma to the major vessels** may of course occur at any age and immediate amputation may be necessary. If so, the level must be chosen according to the site of injury, but if amputation is not an immediate necessity, preliminary control of the bleeding points and sympathectomy should be performed, elective amputation being undertaken at a later date and at a level compatible with the fitting of a useful prosthesis.

2. **Thrombo-angiitis obliterans** is a progressive disease usually affecting young adults; the most frequent form is a gradual obliteration of the vessels starting peripherally and spreading centrally. Sympathectomy will almost invariably have been performed earlier in the disease before amputation becomes necessary. It is important to amputate as low as possible in spite of the fact that the disease tends to progress and that further amputation may be required at a later date; the usual level selected is below the knee at the site of election, but due consideration should also be given to lower amputations, such as local removal of a toe, amputation through the foot or a Syme's procedure.

3. **Arteriosclerosis** is responsible for more amputations being necessary than any other disease. It is a disease of later life, although it may be encountered in earlier age groups. The aim of treatment when amputation becomes necessary is to make the illness as short as possible: *early ambulation is the keynote.* Old people do not respond well to long periods in bed; complications such as venous thrombosis, bed sores, stiff joints and muscle wasting may ensue.

Each case must be judged on its merits, and no low amputation should be performed without good cause to substantiate the operation. Arteriography affords the best indication of the state of the main

vessels and their branches and may assist greatly in deciding the type of operation to be performed. Lumbar sympathectomy undoubtedly improves the chances of achieving a satisfactorily healed stump and should be performed prior to operation whenever possible.

Local amputations through the foot or ankle are sometimes successful, and the advantages of such procedures are obvious, since no complicated prosthesis is required and ambulation may be rapid and easy.

The " above knee " amputation has become the recognized site for the majority of cases of gangrene. The advantage of this procedure is that healing is certain, provided that strict attention to asepsis is observed, but there are numerous disadvantages; thus, old people have great difficulty in managing the prosthesis and to many the difficulty is insuperable, thereby entailing a crippled existence with crutches as the only means of ambulation: a double strain is thereby thrown on the sound limb which is very likely to be subject to the same pathological processes as the one already lost, and double amputation not infrequently becomes necessary. In these unfortunates, it is only possible to achieve ambulation if lower amputations have been employed.

The " below knee " amputation is very much easier to use in combination with an artificial limb, but primary healing cannot always be guaranteed. Careful investigation will allow a proper selection of cases and this level of amputation should be used whenever possible. minor modifications in technique may be advisable. The major disadvantage of the below knee amputation is that a pylon cannot be fitted and the time spent on crutches is necessarily longer.

A further type of amputation which should be considered is the supracondylar or Gritti-Stokes operation, which was the one of choice to an older generation of surgeons and has much to recommend it. This amputation causes much less shock than the ideal " above knee " amputation; moreover, it has been somewhat difficult to rehabilitate the elderly " above knee " amputee with an œdematous stump. The Gritti-Stokes amputation would appear to have fallen out of fashion because of the difficulties of limb fitting rather than for reasons of safety. these difficulties have now been overcome and the operation should once more take its rightful place in amputation surgery. It is a safe procedure and primary healing is certain · in a personal series of 40 cases operated upon by one of the authors (R.J) a sound stump has been achieved in all, and no further gangrene has developed at any time A pylon can be fitted early, followed by an artificial limb which necessitates stiff-legged walking, this, however, is no great handicap, since old people are able to use this stump and prosthesis very much more readily than the " above knee " one The prosthesis is articulated, so that it may be bent for sitting purposes

It should be remembered when amputations at a low level are being considered that some subjects may be suffering from varying degrees of osteo-arthritis of the knee or claudication, and in these patients " below knee " amputations are not satisfactory.

Arteriosclerotic disease in the limbs has been classified by Boyd into four main groups:—

(a) Diffuse obliterative arteritis.
(b) Secondary popliteal thrombosis.
(c) Secondary femoral thrombosis.
(d) Distal type.

Each type has a fairly typical arteriographic picture, but the collateral circulation varies in individual cases and depends to a great extent upon the duration of the obliterative process: if this has been slow and gradual in development, the collateral circulation has a better chance of becoming established. All types are suitable for " above knee " and Gritti-Stokes procedures, but the distal type particularly lends itself to local amputation surgery. The prognosis for other amputations must vary according to the collateral circulation, but in general cases of diffuse arteritis and secondary popliteal thrombosis are more suitable for lower amputations than those with secondary femoral thrombosis.

4. **Embolism.**—Gangrene may result as a sequel to the impaction of an embolus in a main artery, if the collateral circulation is not sufficient to maintain the vitality of the tissues. It is not possible to forecast the site of the block from the extent of the gangrene.

If the case is seen at an early period prior to the death of the tissues, immediate arteriography and embolectomy should be performed, combined with a sympathectomy. The anti-coagulant drugs have greatly enhanced the chances of success in this procedure. When death of tissues has already occurred, a sympathectomy should be done to assist in full dilatation of the collateral circulation, amputation being performed at a later date. It is usually safe to amputate at low levels provided that advanced arteriosclerosis is not present.

5 **Chronic ulceration** of the leg as a result of venous insufficiency is a common occurrence and may occasionally be so severe that amputation is finally required. A " below knee " amputation may be possible in these cases, but frequently a Gritti-Stokes or " above knee " operation has to be performed.

6. **Gangrene** as a result of infection is a local process and requires local excision and drainage as its treatment. Infection and gangrene are, however, associated with diabetes and provided that arteriosclerosis is absent, free drainage and excision coupled with adequate control of the diabetic process is all that is required in treatment. Diabetic gangrene is most commonly, however, arteriosclerotic gangrene in a diabetic subject; in such patients the infection and gangrene are more widespread and toxæmia more severe. The condition requires active and early surgical measures to halt the process, and in this group amputation may be an urgent necessity to eliminate toxæmia.

When arteriosclerotic changes in the vessels are minimal, it is quite safe to perform low or local amputations; but when established

arteriosclerosis is present, the site of election must depend on the extent of the collateral circulation.

7. **Raynaud's disease** and allied phenomena are local conditions, and if gangrene ensues only local amputation is necessary.

8. **Congenital or acquired arterio-venous communications** may result in local necrosis or severe pain. If other measures fail, local amputation has to be performed.

General considerations.—Mention has already been made of the control of sepsis and the maintenance of adequate hæmoglobin concentration, and there are several other factors which are important to observe. In the care of the avascular limb it is necessary to keep the local metabolism as low as possible: this may be done by exposure of the diseased part and by the employment of a bed cradle to keep the bedclothes from the limb. Application of surgical spirit assists in cooling and drying the affected area. *Bulky dressings and hot water bottles all assist in raising local metabolism and should be avoided like the plague.*

At operation close attention to asepsis is imperative: the gangrenous and infected area should be carefully sealed off from the operation site and further preparation of the skin performed after this. Suitable antibiotic cover for the operation should also be employed. It is never necessary to use a tourniquet and it may do harm: the pressure by the tourniquet itself may damage a diseased main vessel and it is also a mistake to deprive the limb of its circulation for the duration of the operation. Severe hæmorrhage is not encountered and the hæmorrhage that does occur can be adequately controlled by the use of hæmostats. Tissues should be handled as gently as possible and unnecessary trauma avoided. Clean and bold cuts with the knife will do less damage than numerous hesitant incisions with the scalpel. Complete hæmostasis must be achieved before closure of the wound and this should be done without a drain. Drainage is quite unnecessary and may be a cause of delayed wound healing or breakdown. At the termination of the operation the wound should be sealed and not disturbed until the removal of the stitches which should not occur until the 14th day. At this time it may be found necessary to keep some stitches in for a further period.

Rehabilitation is of fundamental importance. During the patient's stay in bed daily physiotherapy must be employed, particular attention being paid to the range of movement of all the joints which otherwise may soon become fixed in the aged subject, and also to the general muscle tone. As soon as the wound is healed the patient should be taught to walk on crutches, and no effort should be spared in instruction. The stump itself should be bandaged in the usual manner and an early visit to the limb fitting centre is advisable for the fitting of a pylon where possible, and for the preliminary measurements for the artificial limb.

A recent investigation at Roehampton showed that rehabilitation

of the amputee over 65 years of age was successful in almost 50 per cent. of the patients: the criterion of " success " was not very exacting, but cases were considered to be successful if appreciable and regular daily use was made of the prosthesis for a period of not less than six months from the completion of fitting with the artificial limb and instruction in its use.

Although age is no bar to successful amputation, the rate of failure increases *pari passu* with advancing years.

The prospect of enduring rehabilitation of the elderly amputee is influenced in no small degree by the environment to which the patient returns on discharge from the limb-fitting institution: the solitary existence of an aged amputee, a stairway, lack of incentive to persevere, etc., may undo a promising beginning. Unwarranted optimism concerning what can be done to rehabilitate may be turned by the reality of things to abysmal depression.

Very many of these elderly amputees are themselves poor " medical or surgical risks ": the prospect of successful rehabilitation is adversely influenced by such complications as defects of the contralateral leg, defects of the upper limb, obesity, myocardial disease, defective vision and deafness: the deaf person retires into himself and is difficult to bring into group therapy and into the atmosphere of optimism which can be cultivated in his more fortunate fellows. There seems *no* evidence that wearing a prosthesis shortens life significantly.

Recently, Roehampton has made a case for disarticulation at the knee for elderly amputees: such patients learn to walk more easily and gain balance and confidence more quickly than with the conventional " above knee " amputation. A somewhat more cumbersome prosthesis is required owing to the bulbous stump, and probably the gait will never be as good as that with a prosthesis designed for an ideal " above knee " amputation, but these disadvantages seem to be outweighed by the relative ease of the early rehabilitation.

The Gritti-Stokes amputation has proved its worth in the experience of the authors.

AMPUTATION IN THE PRESENCE OF SEPSIS

In the presence of sepsis it may often be desirable to perform a preliminary amputation with the definite intention of re-amputating or of trimming up the stump on a subsequent occasion. The surgeon should try to perform the preliminary amputation in such a way as to preserve rather more of the limb than is really useful, so that if subsequent operations shorten the stump, its functional utility will not be impaired. For example, in sepsis involving the anterior part of the foot, an amputation may be carried out through the midtarsal region, and when the condition of the stump permits, a re-amputation at Syme's level may be possible. In the same way, if sepsis has extended to the ankle joint or above, the primary amputation should be in the lower third of the leg, so that there remains the possibility of re-amputating at the junction of the proximal and middle thirds of the

leg. In the presence of sepsis an amputation directly through or in close proximity to a large joint is undesirable, so that unless an amputation can be carried out through the leg well below the knee, it is better to go through the lower end of the femur rather than through the knee joint.

The methods of amputating in the presence of sepsis are, briefly, two: (1) the plain circular or guillotine method, and (2) amputation with flaps which are left unsutured, and either temporarily turned back or left with gauze packing between them.

(1) The **circular method** has come in for much hostile criticism, but may have occasional advantages, particularly in acute and virulent infection, such as traumatic gas gangrene. The fact that no tissues are undercut preserves the full vascular supply to the stump, and renders extension of the gangrene less probable.

The level of amputation is fixed by a consideration of the level to

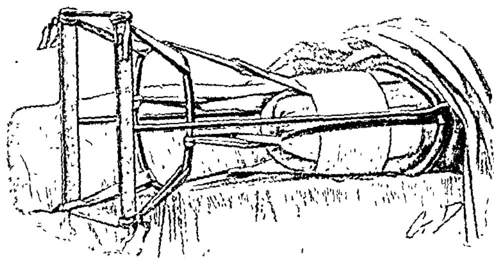


Fig. 76.—Method of carrying out skin extension upon modified Thomas's splint.

which the skin and muscles are infected, bearing in mind the necessity for the entire removal of certain muscles when they have become infected with gas gangrene, and that infection of the deeper planes is more important than of the skin Œdematous skin may be preserved so long as it is a fairly good colour, but an actual infection of a muscle and intermuscular planes beneath the skin indicates amputation at a higher level. The skin is divided by a circular sweep, allowed to retract up the limb slightly, and a second circular cut made to divide the muscles down to the bone; the periosteum is divided, and the bone cut through at the same level; vessels are picked up and tied, nerves shortened, and the wound then dressed with an appropriate antiseptic and left entirely unsutured

The immediate after-treatment of the stump is chiefly designed to subdue the septic infection.

If an amputation performed by this method is left to granulate, great retraction of the skin and muscles is apt to take place. It is,

therefore, necessary to carry out *after-treatment* by extension on the skin to diminish the retraction and minimize the subsequent operative measures required. A simple method is shown in Fig. 76. A splint similar to a Thomas's knee splint with a ring round the top of the thigh (or the shoulder), but with a square frame at its other end, is applied to the stump. Four extension straps are stuck to the skin on different aspects of the stump, either by adhesive strapping or with Sinclair's glue, and these are attached to a ring which can then be pulled down and fastened to the frame at the end of the Thomas's splint. Extension on the skin is thus made without interfering with the wound at the end, which can be dressed without disturbing the splint.

(2) **An amputation with flaps left unsutured** is carried out in the way already described for amputations through the leg or thigh. The flap is cut from whichever aspect is desired, reflected back as a skin-flap, and the rest of the limb then divided at the level of the base of the flap. A single flap on one aspect of the limb or equal or unequal flaps taken from opposite aspects, may be used, in accordance with the skin available. When the amputation has been completed, the flaps are not sutured, but are turned back, an antiseptic dressing is applied to the cut surface of the stump, or alternatively the dressing is packed in between them. Skin extension will be needed just as in the guillotine amputation, except in small amputations such as those of the fingers; in fact, the subsequent treatment of amputations done by the two methods is identical.

When an amputation carried out in the presence of sepsis has been allowed to granulate and is looking healthy, its final treatment must depend upon several factors, viz. (1) the level of amputation and the desirability of shortening; (2) the condition of the cut end of the bone, particularly whether there is or is not necrosis; and (3) the amount of skin available to cover in the granulating area. If the amputation has been carried out at a site which renders shortening of the stump desirable, e g. through the middle of the tarsus or the lower third of the leg, as soon as the wound is granulating in a healthy way and the rest of the stump is free from œdema, a complete re-amputation at the best level immediately above should be carried out, for example, amputation at Syme's level or amputation through the middle third of the leg. If the level of the amputation renders it inadvisable to shorten the stump, a secondary suture of the skin over the end of the stump should be carried out, if possible. The possibility depends on the condition of the bone; if there is necrosis, a ring sequestrum will form and secondary suture cannot be done until this has separated. Moreover, the skin available may not be quite sufficient to cover in the end of the stump, and the removal of a small additional portion of bone may be required. The removal of this by an incision through the granulating area will almost certainly be dangerous, involving a possible infection of the end of the bone and additional necrosis. The procedures then required for dealing with such a stump are, briefly, (1) secondary suture when

the bone is healthy and the skin sufficient to cover in the stum (2) secondary suture after an interval sufficient to allow of the sepa tion and removal of any necrosed bone; (3) re-amputation as soon possible above the original site when the skin is insufficient to co over the stump. The first can be carried out without delay; t second necessitates a considerable interval; the third may be done soon as the granulations are healthy and the stump free from œden provided that the infection of the bone does not extend upwards far as the level at which re-amputation is desired. The first a second of these procedures requires no special description.

RE-AMPUTATION OF A GRANULATING STUMP

Re-amputation of a granulating stump should be carried out (1) wh the stump has to be considerably shortened, and (2) when every possil inch of bone has to be retained.

(1) *When the stump has to be considerably shortened* the re-ampu tion requires no special description; it is only necessary for the surge to remember that he has a granulating and probably infected wou at the end of the stump, and to take precautions against infection of t new wound. An appropriate antibiotic " umbrella " should be e ployed. The granulating area may be treated, as a preliminary, wi a powerful antiseptic, such as pure carbolic acid, and covered up wi an adherent dressing (collodion) before the operation begins.

(2) *When it is necessary to preserve as much as possible of the stum* re-amputation can usually be carried out and aseptic healing secur if precautions are taken as follows. The stump is suitably prepar on the day before operation; at operation the granulating surface a any sinus there may be are swabbed out with pure carbolic acid, t rest of the skin being repainted with an antiseptic of choice. T surgeon marks out his flaps, preserving all the skin available, keepi his knife just clear of the granulating area and of the thin ingrowi epithelium, and at the same time removing all superficial scars. The flaps are picked up with tissue-forceps and reflected back as skin-fla With a second knife the muscles are cut through right down to t bone; this is sawn across at the required level, which must be hi enough to preclude any possibility of finding a patch of necros During the whole of this part of the operation the surgeon and h assistants must take care never to touch the end of the stump wi their hands, with an instrument or with a swab. In fact, it is bett to avoid using any swabs up to the time at which the bone is sever and the end of the stump removed. As soon as the bone has be divided, the rest of the operation can be carried out as in any asept amputation, the wound being sutured, with drainage employed f forty-eight hours.

SUCTION SOCKETS

Since 1860 various attempts have been made in many countri to fit " above knee " amputees with what has been termed a sucti

CHAPTER VI

OPERATIONS ON BONES

By H. JACKSON BURROWS

SOME PRINCIPLES OF BONE SURGERY

THE approach to bone surgery should be the restoration of function—and often form also—to the skeletal system. As this usually implies the surgery of the limbs, and, as bone has a hard consistency, some modifications of general surgical technique are required. It is important to bear in mind that bone is a living tissue, dependent upon a blood supply for survival, growth and repair; bone should be treated with respect; it should not be stripped unnecessarily or seared with the heat of motor-driven tools. Growth and repair are much affected also by the general health of the patient, whose diet, hæmoglobin, etc., need attention. Ultimate function depends not only upon what is done to a bone and how it responds to intervention but also upon other parts, such as muscles and joints, a fact which influences not only the planning of surgical approaches, so that they avoid unnecessary damage by division or stretching, but also the whole management and "after-treatment" of the patient in general and the affected part in particular. Function is much more readily restored in the young, but in them there is the special responsibility of preserving epiphyseal growth. In many bone operations, damage to surrounding parts is diminished by carrying out the essential procedures subperiosteally; that is to say that, once the periosteum has been reached and opened, all else is carried out beneath it.

INSTRUMENTS USED IN BONE SURGERY

Technical failure in bone operations is often caused by an insufficiency of instruments, badly selected instruments or, worst of all, a superabundance of instruments which the operator has not learned to master and which jostle with their fellows on the sister's table. In few branches of surgery is it more necessary to select the instruments carefully, to master them thoroughly and to exclude all that are redundant. For these reasons, no apology is made for this very elementary section. The more important bone tools may be classified as (1) cutting instruments, (2) piercing instruments, (3) scraping instruments, (4) holding instruments.

(1) Cutting instruments.—These consist of (*a*) percussion instruments, (*b*) bone cutting forceps, and (*c*) saws.

(a) Percussion instruments.—These comprise chisels, osteotomes and gouges of various widths, and their accessory, the mallet. The *chisel* resembles the carpenter's rather than the engineer's in having the

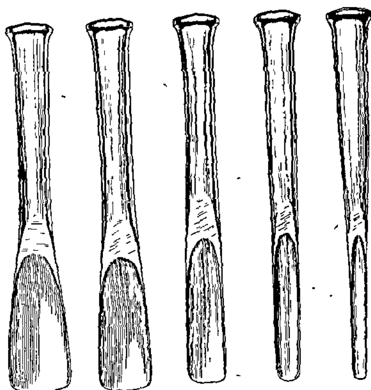


Fig. 77.—Gouges of various widths and curvatures.

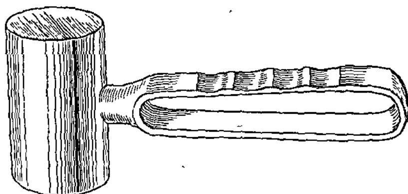


Fig. 78.—Mallet (Heath's). The short handle allows better control than a long one.

blade bevelled on one surface only so that it does *not* cut strictly in the axis in which the instrument is struck. For this reason the *osteotome* is nearly always preferred. Its blade is bevelled gradually on both surfaces so that the direction of cut corresponds to the axis of the instrument. Various widths are required, the most generally useful being ½ in. and ¾ in., and the stoutness also may be varied; relatively

stout instruments, such as Macewen's, are suitable for the simpler osteotomies, but thinner osteotomes, which require more care in use, are preferable for finer work which would be spoilt by splitting the bone. *Gouges* (Fig. 77), made in various widths, curvatures and thicknesses, have the bevel on the convex facé of the blade and resemble the carpenter's outside-ground chisel. *The mallet*, easily forgotten, is most readily controlled if it resembles the mason's in having a relatively heavy head and short handle (Fig. 78).

(b) Bone cutting forceps.—The bite may be strengthened at the

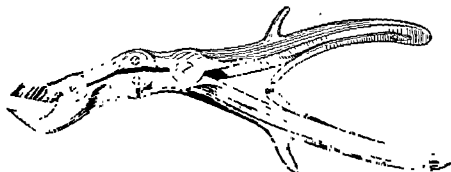


Fig. 79.—Powerful bone cutting forceps (Key's).

expense of rapidity by the use of a system of double levers (Fig. 79). Forceps which bite the bone by opposing gouge-like blades, instead of by opposing straight or curved shear-like blades, are known as *nibbling forceps*, *gouge forceps* or *rongeurs* (Fig. 80).

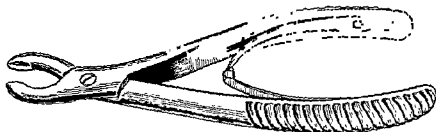


Fig. 80.—Nibbling or gouge forceps.

(c) Saws.—Those of practical importance are· amputation saw, wire saw (Gigli's) and circular saw (motor saw). The *amputation saw* is used for the division of large bones in major amputations and sometimes in excision of major joints, arthrodesis and arthroplasty. *Gigli's saw* is used for smaller bones, such as the phalanges of the great toe and in cranial surgery. In using this instrument the wire should be kept as straight as possible, the handles being held widely separated and the cuts made in a sweeping manner, if, on the contrary, the cutting wire is allowed to approach the shape of a letter U it will break. The

modern Olivecrona modification is less likely to do so. A spare wire should be at hand. The *motor saw* in common use is a circular saw driven by an electric or pneumatic motor. The saw may be single, having one blade, or "twin", two blades being mounted so that parallel cuts may be made simultaneously. The motor is connected by intermediate shafting to the saw by means of a chuck capable of taking also alternative instruments, such as drills, suitably adapted to it. The motor should be tested before each operation. Whenever the saw, or other tool, is not actually in use, and especially when it is being changed, the power should be cut off lest an accidental manipulation of the operator's switch should cause a serious accident. (With a pneumatic motor, the tubing should then be emptied by momentarily restarting the motor.) In cutting with the saw the following points should be borne in mind: to cut the correct way of the saw, with most models from the operator's left to right; to hold very firmly, because otherwise the saw may run along the bone and over the edge, and so damage the soft tissues; to avoid striking other instruments, such as bone levers, and to keep the assistants' fingers well away; to cut in strictly straight lines, and not to attempt to produce curves, which stall the

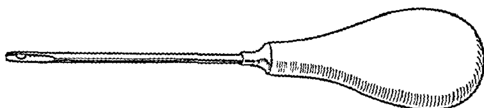


Fig. 81.—Awl (Bankart's). Note that the eye should be large and oval.

motor or break the saw; because of this possibility not to hold the head in the plane of the blade; not to overheat the saw. The dangers of the circular saw are overcome by the use of an oscillating motion instead of the spinning motion. Curves may be cut with special motor-driven drills in place of the saw.

(2) Piercing instruments.—These are merely specialized forms of cutting instruments. The most important are: (*a*) trephines, (*b*) burrs, (*c*) awls, and (*d*) drills.

(a) and (b) Trephines and burrs.—These are illustrated in Chapters VIII (Fig. 187) and XXVI.

(c) Awls.—The *instrument shown in Fig. 81*, with a semi-circular cross section is the most satisfactory. To facilitate threading, the eye should be as large as is consistent with adequate strength. If, as usual, hand-driven, the instrument should be kept very sharp and have an adequate handle. Awls are used principally for passing suture materials through bone. Two should be available because of occasional breakage.

(d) Drills.—These are usually carpenter's Morse twist drills of various sizes, but it is better that the channelling should be confined to

the terminal half inch (Fig. 100). They are driven by a handstock or a motor. Drills are used for making larger tunnels than those possible with the awl, or for making holes of standard bore, such as screw holes.

(3) Scraping instruments.—Three of these require description: the rugine, the Volkmann's spoon and the file.

The rugine, periosteal elevator or raspatory.—Of the many forms of this instrument, the most commonly used is Farabeuf's (Fig. 82), which may have either a straight or curved extremity; the straight instrument is unnecessary. The rugine denudes fascia as efficiently as bone.

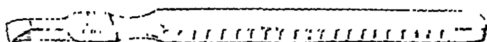


Fig. 82.—Rugine (Farabeuf's). Only the curved variety is needed.

The Volkmann's spoon.—Of various sizes, these are a variety of *curette*, but are also useful for lifting slippery loose bodies from cavities such as joints.

The file or rasp (contrast "raspatory" above).—A useful refinement for smoothing the bone ends in arthroplasties and amputations or, conversely, roughening tendons and fascial strips intended to become attached.

(4) Holding instruments.—These may be grouped into: (*a*) grasping instruments, and (*b*) levers.

(a) Grasping instruments.—Among many forms, the classical instrument is the *lion forceps*. For large bones, such as the femur, an instrument with longer shanks is useful (Fig. 83). A modification with a ratchet (Fig. 102, p. 271) is an invaluable clamp in bone screwing, plating and grafting.

(b) Bone levers.—Bone levers (Figs. 84 and 85) not only steady the bone but serve as retractors. The tip of the instrument is slipped between bone and elevated periosteum, and the assistant holds the

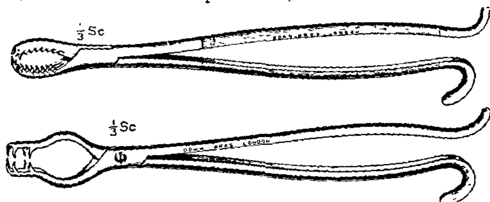


Fig. 83.—Bone holding forceps (Lane's). The lower instrument will grip bones of more varied thickness than the upper.

handle; usually the instruments are used in pairs (Fig. 86), so that, when the handles are separated, the soft tissues are retracted and the bone is exposed and steadied. These instruments are important

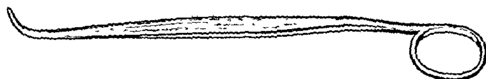


Fig. 84. Small bone lever (Trethowan's).



Fig. 85.—Large bone lever (Fagge's modification of Lane's).

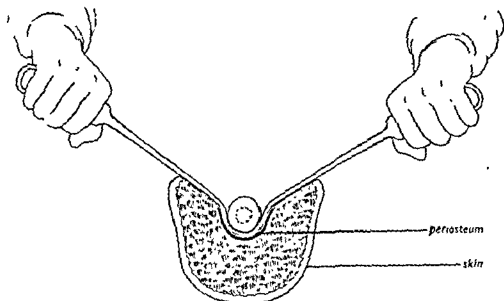


Fig. 86.—Diagram to show the method of retraction of soft tissues with bone levers.

practical aids, because the only safe method of performing some bone operations is subperiosteally. Yet bone levers receive scant attention in the textbooks and were rarely, if ever, provided for operations on the cadaver by students, who were obliged to improvise. Levers with guttered ends for guiding the dislocated extremity of a bone into place are known as skids, but gouges form a satisfactory substitute, provided the potential danger of their cutting edge is borne in mind.

EXPOSURE OF THE SHAFTS OF THE LONG BONES

Complete mastery of the exposure of bones must be the basis of bone surgery. The ends of the bone are exposed in the major approaches to joints; and only the approach to the shafts need be considered in this chapter There has been a tendency to use

incisions worked out in the cadaver for the purpose of exposing the whole length of a bone,* but it is hardly ever necessary to expose the whole of the bone and probably never necessary to do so through a single incision. Such incisions are not invariably the best. The chosen incision should rather be the one that provides the best possible exposure in the living for the procedure required, with the least possible damage and risk.

Indications.—A part or whole of the shaft of a long bone may require exposure for one of the following procedures.

(1) Open reduction of fractures, with or without the application of internal splinting.

(2) Reconstruction of fractures that have started uniting in bad position.

(3) [illegible]

(4) [illegible]

(5) [illegible]

(6) Bone grafting—preparation of both the host bone and the bone furnishing the graft.

Instruments.—The following are required in addition to the soft tissue foundation set. rugine, bone levers and, in some instances, deep retractors. These are the instruments for exposure only; others may be needed for operation upon the duly exposed bone.

Exposure of the upper third of the shaft of the femur. Special indication.—The most frequent purposes for the exposure are insertion of a nail in the femoral neck, osteotomy, curettage, ischio-femoral arthrodesis and drainage.

Position.—The patient is placed on his back with the buttock of the side of operation raised on a sand-bag, which is well pushed home so as to be removed from the field of operation

Operation.—The base of the great trochanter is defined and a lateral incision is made through skin and superficial fascia over the upper third of the femur. The incision is carried distally from the great trochanter and very slightly forwards to allow for the curvature of the bone The deep structures are divided in the line of the original incision down to bone. The knife divides the following structures from without inwards, (1) the fascia lata (femoris), with (proximally) the muscles inserted into it, namely tensor fasciæ latæ (femoris) and part of gluteus maximus, (2) the vastus lateralis and vastus intermedius (crureus) and (3) the periosteum. This is stripped from the bone with a rugine, and levers are inserted so that they hold the soft tissues retracted. In closure, suturing is carried out in three or four layers: (1) the vasti, (2) the fascia lata, (3) the superficial fascia, if thick, and (4) skin.

* Henry, Arnold K., *Exposure of Long Bones and other Surgical Methods*, 1927, Bristol John Wright & Sons Ltd, and *Extensile Exposure applied to Limb Surgery*, 1945, Edinburgh E. & S. Livingstone Ltd

Exposure of the middle third of the shaft of the femur. Special indication.—The most frequent purposes are for (1) open operations on fractures, and (2) drainage in osteomyelitis.

Position.—The patient is placed on his back with a sand-bag under the buttock of the side to be operated upon.

Methods.—Three approaches will be described: (1) behind vastus lateralis, (2) through vastus lateralis, and (3) in front of vastus lateralis. (A posterior approach also has been described by Bosworth,* but this, like a medial approach, transgresses the principle of steering well clear of important anatomical structures ; it is rarely called for.)

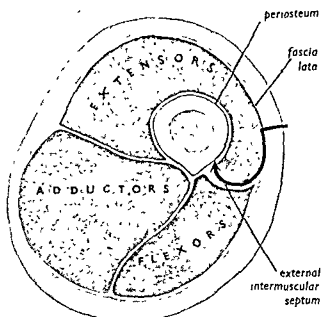


Fig. 87.—Diagrammatic cross section of the thigh to show the method of approach behind vastus lateralis (externus) to the middle third of the femoral shaft.

(1) In the method in which the approach is made behind the vastus lateralis the skin and superficial fascia are incised on the outer aspect of the thigh in the line of the bone. The deep fascia is split throughout the length of the incision, exposing the vastus lateralis. This is separated from the lateral intermuscular septum and retracted forwards by an assistant, and the knife is carried to the bone just lateral to the linea aspera throughout the length of the wound. The vastus intermedius (crureus) is then separated from the shaft of the femur with a rugine, and the whole muscle mass is held forwards by bone levers introduced across the front of the bone. (Fig. 87.)

In closing the wound, the quadriceps is allowed to fall back into place, and sutures are inserted in the deep fascia, perhaps the superficial fascia, and the skin.

* Bosworth, David M., "Posterior Approach to the Femur," *J. Bone Jt Surg*, 1944, xxvi, 687

Comment: This approach to the middle of the femur involves least division of muscle, and the writer prefers it, but perforating branches of the deep femoral artery are capable of fierce hæmorrhage.

(2) In the approach through the vastus lateralis a lateral skin incision is made, as in the last operation, but the muscles are split in its line, instead of being prised forwards after separation from the lateral intermuscular septum.

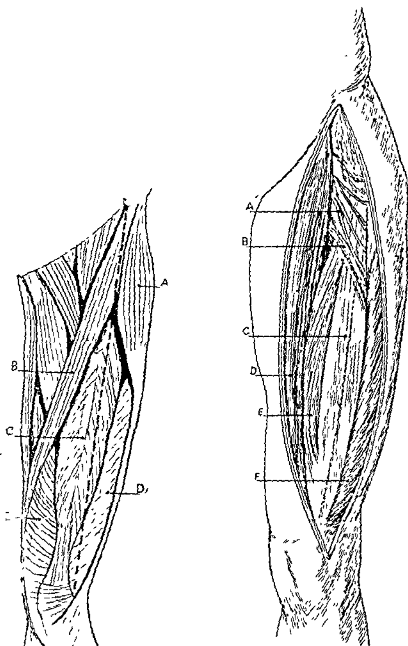


Fig. 88.—Henry's illustrations of the approach to the femur in front of vastus lateralis. (*Brit. Journ. Surg.*, 1924-5, xii)

A, Tensor fasciæ latæ (femoris) B, Sartorius C, Rectus femoris D, Vastus lateralis (externus) E, Vastus medialis (internus)

A, Nerve to vastus lateralis (externus)

Comment: This direct access is the simplest but involves too much muscle damage to be recommended.

(3) The last method to be given, the approach in front of the vastus lateralis, ascribed to Thompson,* is often erroneously called Henry's.† An antero-lateral skin incision is made *in part of an imaginary line joining the anterior superior iliac spine* and the lateral margin of the patella. The deep fascia is divided over the interval between vastus lateralis and rectus femoris, which are separated, exposing vastus intermedius (crureus). This is crossed from above downwards and outwards by the descending branch of the lateral circumflex artery and its veins and by the nerve to vastus lateralis; if these encroach on the upper part of the wound they are retracted upwards The bone is reached by division of the vastus intermedius and the underlying periosteum. (Fig. 88.)

Comment: This approach is not always as bloodless as it is painted, and it involves division of a considerable thickness of the quadriceps in the part where a scar is least desirable.

Exposure of the lower third of the shaft of the femur. *Special indications.*—The approach is most frequently undertaken for the treatment of fractures, drainage, or biopsy.

Particular points to be borne in mind in exposing the lower third of the femur for septic conditions.—The bone should not be explored from the inner side, because the relative closeness of the femoral (superficial femoral) artery makes proximal extension of the incision difficult and is particularly troublesome if the operation is followed by sinus formation. Unless the knee is already infected the greatest care must be taken not to open it. The suprapatellar pouch, extending a hand's breadth above the upper margin of the patella, laps round the sides of the lower end of the femur farther than is usually supposed, so that, although separated from the bone by fat, it is readily opened if the operation is carried too far forwards or if bone levers are passed across the front of the bone. The other part of the knee particularly endangered is the synovial pouch behind the lateral condyle, if the incision is carried too far distally this pouch may be opened. Because of the presence of the suprapatellar pouch, openings into the bone necessarily encroach extensively on the popliteal surface of the femur, this is devoid of muscle capable of falling readily into the cavity, and because of the absence of muscle attachments is poorly supplied with blood; hence sinus formation is frequent and difficult to counter.

Position.—The patient is placed on the sound side with the corresponding lower limb fully extended or fully flexed. The knee of the affected limb lies semiflexed on a thick sandbag.

Operation.—The incision through skin and superficial fascia follows

* Thompson, James E., "Anatomical Methods of Approach in Operations on the Long Bones of the Extremities," *Ann Surg*, 1918, lxviii, 309

† Henry, Arnold K., "Exposure of the Humerus and Femoral Shaft," *Brit J. Surg*, 1924, xii, 84

Comment: This approach to the middle of the femur involves least division of muscle, and the writer prefers it, but perforating *branches of the deep femoral artery are capable of fierce hæmorrhage.*

(2) In the approach through the vastus lateralis a lateral skin incision is made, as in the last operation, but the muscles are split in its line, instead of being prised forwards after separation from the lateral intermuscular septum.

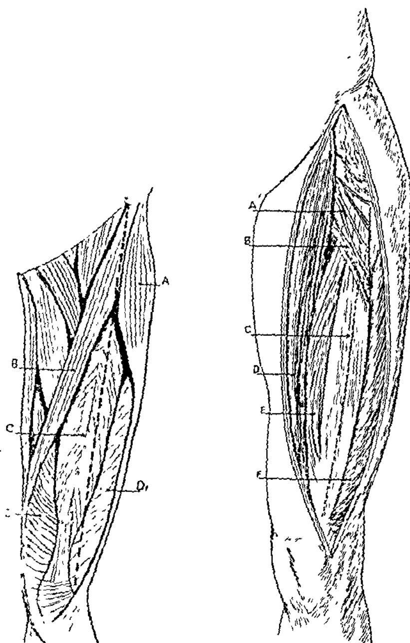


Fig. 88.—Henry's illustrations of the approach to the femur in *front of vastus lateralis.* (*Brit Journ Surg.*, 1924-5, xii.)

A, Tensor fasciæ latæ (femoris) B, Sartorius C, Rectus femoris D, Vastus lateralis (externus) E, Vastus medialis (internus)

A, Nerve to vastus lateralis (externus) B, Descending branch of lateral (external) circumflex artery, with veins C, Vastus intermedius (crureus) D, Rectus femoris E, Vastus medialis (internus) F, Vastus lateralis (externus)

Comment. This direct access is the simplest but involves too much muscle damage to be recommended.

(3) The last method to be given, the approach in front of the vastus lateralis, ascribed to Thompson,* is often erroneously called Henry's.† An antero-lateral skin incision is made in part of an imaginary line joining the anterior superior iliac spine and the lateral margin of the patella. The deep fascia is divided over the interval between vastus lateralis and rectus femoris, which are separated, exposing vastus intermedius (crureus). This is crossed from above downwards and outwards by the descending branch of the lateral circumflex artery and its veins and by the nerve to vastus lateralis; if these encroach on the upper part of the wound they are retracted upwards. The bone is reached by division of the vastus intermedius and the underlying periosteum. (Fig. 88.)

Comment: This approach is not always as bloodless as it is painted, and it involves division of a considerable thickness of the quadriceps in the part where a scar is least desirable.

Exposure of the lower third of the shaft of the femur. **Special indications.**—The approach is most frequently undertaken for the treatment of fractures, drainage, or biopsy.

Particular points to be borne in mind in exposing the lower third of the femur for septic conditions.—The bone should not be explored from the inner side, because the relative closeness of the femoral (superficial femoral) artery makes proximal extension of the incision difficult and is particularly troublesome if the operation is followed by sinus formation. Unless the knee is already infected the greatest care must be taken not to open it. The suprapatellar pouch, extending a hand's breadth above the upper margin of the patella, laps round the sides of the lower end of the femur farther than is usually supposed, so that, although separated from the bone by fat, it is readily opened if the operation is carried too far forwards or if bone levers are passed across the front of the bone. The other part of the knee particularly endangered is the synovial pouch behind the lateral condyle; if the incision is carried too far distally this pouch may be opened Because of the presence of the suprapatellar pouch, openings into the bone necessarily encroach extensively on the popliteal surface of the femur; this is devoid of muscle capable of falling readily into the cavity, and because of the absence of muscle attachments is poorly supplied with blood; hence sinus formation is frequent and difficult to counter.

Position.—The patient is placed on the sound side with the corresponding lower limb fully extended or fully flexed. The knee of the affected limb lies semiflexed on a thick sandbag.

Operation.—The incision through skin and superficial fascia follows

* Thompson, James E., "Anatomical Methods of Approach in Operations on the Long Bones of the Extremities," *Ann. Surg.*, 1918, lxviii, 309.

† Henry, Arnold K., "Exposure of the Humerus and Femoral Shaft," *Brit. J. Surg.*, 1924, xii, 84

the posterior margin of the ilio-tibial band, and ends distally at a point proximal to the upper margin of the lateral femoral condyle. The deep fascia is divided in the same line. The biceps femoris is separated from the back of the lateral intermuscular septum. The periosteum is opened and bone levers are inserted behind the bone to retract the biceps and the contents of the popliteal fossa; the intermuscular septum and tissues anterior to it are held forwards by retractors, because the use of bone levers in front of the bone would endanger the suprapatellar pouch.

Exposure of the shaft of the tibia. Special indications.—Approach to the tibia is required for operations on fractures, the removal of bone for grafting, osteotomy, biopsy, and drainage.

Position.—The patient is placed on his back; the lower limbs rotate outwards spontaneously, bringing the inner surfaces of the tibiæ forwards. It is sometimes convenient to elevate the leg upon a sandbag.

Operation.—Because the inner surface of the tibia is entirely subcutaneous (except at its upper end, where sartorius, gracilis and semitendinosus are inserted), no special description of the exposure is required, except to say that a straight skin incision of adequate length, just clear of the subcutaneous surface of the bone, is preferable to the customary curved incision. As the lower third of the leg is approached, the inner surface faces increasingly inwards, the anterior crest (which is here not very distinct) curving medially and the outer surface coming to face forwards; unless the twist in the subcutaneous surface is remembered, the surgeon may, in the lower third, transgress the anterior soft tissue compartment.

Exposure of the upper half of the fibula. Indications.—The approach may be required for diaphysectomy in the treatment of acute or chronic osteomyelitis or for resection of a new growth or cyst.

Anatomy.—The approach is governed by the necessity of avoiding damage to the lateral popliteal (common peroneal) nerve. This passes through the popliteal fossa medial to the biceps femoris tendon and leaves the fossa by passing superficial to the lateral head of gastrocnemius. At the level of insertion of the biceps tendon the nerve lies behind this, separated from the fibular head by the soleus (Fig. 89). It dips between this muscle and peroneus longus to wind round the neck of the bone deep to the latter. Here it divides into its anterior tibial (deep peroneal) and musculo-cutaneous (superficial peroneal) terminal branches. The latter of these passes downwards almost in contact with the bone as far as about the middle of the leg, where it becomes separated by the peroneus brevis. The anterior tibial artery, near its origin, may groove the interosseous crest at the lower part of the fibular neck in passing forwards to enter the anterior musculo-fascial compartment of the leg The peroneal vessels lie close to the postero-medial border on the surface of tibialis posterior (posticus); they provide the nutrient vessels, the nutrient artery entering the bone in a downward direction at about the middle of the posterior

surface. The close relationship of important structures emphasizes the need of keeping next to the bone in clearing the soft structures, a procedure which is rendered much more difficult by the attachments of intermuscular septa, which do not yield to the rugine and require the use of the scalpel.

Position.—The patient is placed on his sound side, with the corresponding limb extended and the limb for operation semiflexed at hip and knee.

Operation.—An incision through skin and superficial fascia is made in the line of the posterior margin of the bone in its upper third and is extended for about an inch and a half along the biceps tendon, care being taken not to cut so deeply as to endanger the lateral popliteal nerve. This is defined from where it lies in relationship to the tendon forwards and downwards to the point opposite the neck of the fibula at which it disappears deep to the peroneus longus. The defined portion of nerve is mobilized and retracted forwards. The deep fascia is divided over the line of contiguity between soleus and peroneus longus, and the intervening plane of cleavage is opened. The periosteum of the fibula is incised along the posterior margin of the peroneus longus origin and elevated. The periosteum and the peroneus longus, with its contained lateral popliteal and musculo-cutaneous nerves, are thus carried forwards and they are held so with bone levers. In clearing the periosteum from the back and inner aspect care must be taken to avoid injury to the anterior tibial and peroneal arteries.

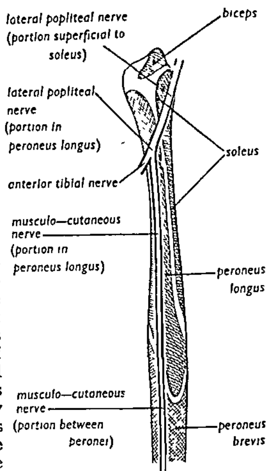


Fig. 89.—Outer aspect of the upper two-thirds of the left fibula, showing the muscle attachments and the relationship of the lateral popliteal (common peroneal) nerve and its two terminal branches. In exposure of the upper half of the fibula the portion of the lateral popliteal nerve superficial to the soleus is retracted forwards and the bone is approached between the soleus and the peroneus longus (i.e. along the posterior peroneal septum —*see* Fig. 90).

Exposure of the lower half of the fibula. Indications.—The approach may be required for partial diaphysectomy, either in the treatment of osteomyelitis or, rarely nowadays, for the provision of a bone graft comprising part of the length of the fibula. It is often wise to excise about an inch of the fibular diaphysis in operations for tibial

non-union. Osteotomy of the fibula is required if it cannot be broken in the course of osteotomy of the tibia.

Anatomy.—The lowest part of the fibular shaft presents a subcutaneous area, the apex of which is continuous with the antero-lateral border, which curves gradually forwards so as to reach the front of the bone at about the middle of the leg. This border gives attachment to the anterior peroneal septum (Fig. 90), which separates the peroneal muscles proper from the anterior tibial group and provides the most suitable plane of access to the bone in its lower half, just as the posterior peroneal septum does in the upper half. The close relationship of the peroneal vessels to the deep surface of the bone must be remembered in clearing it.

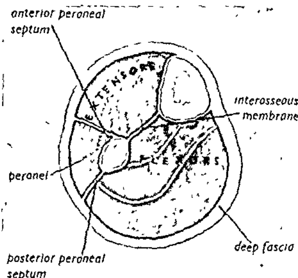


Fig. 90.—Diagram of the intermuscular septa of the calf.

Position.—The patient is placed in the dorsal position, tilted slightly away from the side of operation.

Operation.—An incision through skin and superficial fascia is carried from the outer aspect of the fibula at the ankle vertically upwards to reach the middle of the leg. The margins are separated from the deep fascia for about an inch in either direction, forwards and backwards. In this process the terminal part of the musculo-cutaneous nerve may be seen piercing the deep fascia at about the junction of the upper and middle thirds of the incision The nerve here provides a guide to the interval between the peronei and extensor digitorum longus The periosteum over the subcutaneous area of the fibula is incised in the line of the wound, and the division is carried upwards through the deep fascia just behind the anterior peroneal septum. The fibres of peroneus brevis are separated from the postero-lateral aspect of this until the periosteum is reached. The periosteal incision in the subcutaneous area can then be extended upwards to the middle of the leg. The periosteum is separated with

a rugine, supplemented by a scalpel at the attachments of intermuscular septa to the borders, care being taken to avoid injury to the peroneal vessels lying in close relationship to the deep surface. Bone levers are then inserted deep to the periosteum so that they can be used to retract the soft tissues.

Exposure of the upper half of the shaft of the humerus. Indications.—Exposure of the shaft of the humerus in its upper half, or in part of it, with or without the head, may be required in various conditions of which the following are examples: (*a*) fractures, including fracture of the surgical neck complicated by dislocation of the shoulder, (*b*) metaphyseal cysts, (*c*) acute or chronic osteomyelitis, (*d*) metaphyseal abscess, (*e*) new growths, (*f*) defects of the tendon of the long head of biceps needing tenodesis.

Operation.—This corresponds with that described for exposure of the shoulder joint except that the incision is prolonged downwards to the middle of the arm.

Exposure of the lower half of the shaft of the humerus. Indications.—The principal indications are, (*a*) ununited or complicated fracture, (*b*) biopsy, and (*c*) osteomyelitis.

Anatomy.—The most convenient approach is from behind through the triceps muscle.* Besides the elbow in septic cases, the only important structure which needs special attention is the radial (musculo-spiral) nerve which crosses the back of the humerus obliquely from within outwards at its middle Damage to other important structures is avoided by keeping deep to the periosteum once this has been opened.

Position.—The patient is placed prone, with the limb, abducted at the shoulder and extended at the elbow, lying at right angles to the trunk upon a sandbag placed on an arm table.

Operation.—An axial incision through skin and superficial fascia is made down the back of the arm from its middle to the tip of the olecranon. The incision is deepened through the deep fascia and triceps muscle In the upper part the fibres must be carefully separated by blunt dissection until the radial nerve has been found next the bone and retracted upwards and outwards The periosteum is then divided through the length of the wound and separated with a rugine, after which bone levers may be inserted to act as retractors. In septic cases which do not involve the elbow, care must be taken not to open this.

Exposure of the shaft of the ulna. Indications.—The most frequent indications are (*a*) open reduction of an ulnar fracture that cannot be satisfactorily treated by conservative means, for example some of the cases associated with fracture of the radius or dislocation of its head, (*b*) operations for mal-union, (*c*) bone grafting operations for non-union or occasionally for failure of regeneration after diaphysectomy, (*d*) operations for osteomyelitis.

* For an alternative approach through brachialis (brachialis anticus), *see* Henry, Arnold K., "Exposure of the Humerus and Femoral Shaft," *Brit J Surg*, 1924, xii, 84

Anatomy.—The posterior or dorsal border is subcutaneous throughout its extent from the apex of the subcutaneous triangular area at the back of the olecranon to the styloid process. The lower quarter is smooth and ill-defined. The upper, prominent part gives attachment to the deep fascia; this blends laterally with the anconeus and the aponeurotic origin of extensor carpi ulnaris, and medially with the similar origins of flexor carpi ulnaris and flexor digitorum profundus.

Position.—The patient is placed on his back with the limb abducted at the shoulder and flexed at the elbow; the forearm is placed prone on a sandbag lying on an arm table.

Operation.—A straight incision through skin and superficial fascia is made from the subcutaneous surface of the olecranon to a point proximal to the base of the styloid process. It should be remembered

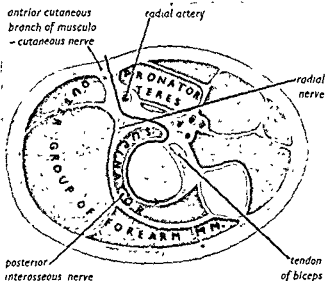


Fig. 91.—Diagrammatic transverse section in the upper third of the forearm to show the method of exposure of the upper third of the shaft of the radius.

that the prominence above the back of the wrist in the attitude of pronation is *not* the styloid process, but the back of the head of the ulna. The margins of the wound are dissected from the deep fascia enough to define the subcutaneous surface of the ulna. The periosteum over the smooth lower part of the posterior border of the ulna is divided; the periosteal incision is then continued proximally close along each side of the prominent upper three-quarters of the border. The incision along the outer margin of the border divides the deep fascia with the blended aponeurotic origin of extensor carpi ulnaris, part of the anconeus insertion and the periosteum, the incision along the inner margin of the border divides the similarly blended deep fascia, flexor carpi ulnaris, flexor digitorum profundus and periosteum. The periosteum, with its soft-tissue attachments, is cleared from the bone outwards and inwards, and bone levers are inserted. In septic

conditions not involving the lower radio-ulnar joint care should be taken to avoid the upwardly projecting recessus sacciformis.

Exposure of the upper third of the shaft of the radius. Indications.—The most common purposes for exposing the upper third of the radial shaft are, (*a*) open correction of a fracture, and (*b*) operations for osteomyelitis.

Anatomy.—The head and neck of the bone are very easily approached from behind, as described in Chapter III, but the shaft of the upper part of the bone must be approached from in front. The planning of the exposure of the shaft depends upon the necessity of avoiding injury to the

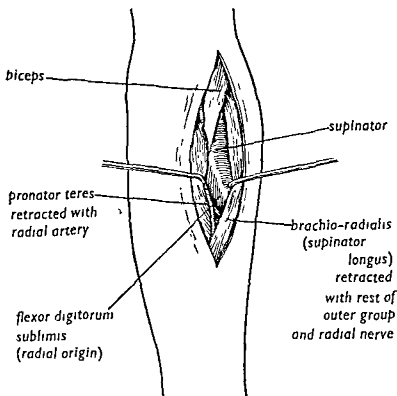


Fig 92.—Approach to upper third of the shaft of the radius: anterior edge of radial attachment of supinator (supinator brevis) exposed.

posterior interosseous nerve (dorsal interosseous nerve, deep branch of radial nerve) by turning it backwards with the supinator (supinator brevis), in which it is embedded (Fig. 91). The deep-lying field of this procedure is approached by separation of the outer group of forearm muscles with the radial nerve (superficial branch of the radial nerve) from the biceps tendon, the pronator teres (pronator radii teres) and the radial vessels (Fig. 92). The radial recurrent vessels are met in the upper part of the plane of separation. The radial nerve and artery meet at the junction of the upper and middle thirds of the forearm.

Position.—The patient is placed on his back with the arm abducted over an arm table: the forearm lies supine on a sandbag with the elbow extended.

Operation.—A straight incision is made from the outer edge of the biceps, about one inch proximal to the bend of the elbow, vertically downwards almost to the middle of the forearm. The lateral cutaneous nerve of the forearm (anterior cutaneous branch of the musculo-cutaneous nerve) may be encountered. The deep fascia is divided, the outer side of the biceps tendon being exposed. The interval between the outer group of forearm muscles and the pronator teres (pronator radii teres) is defined. This plane is opened out by blunt

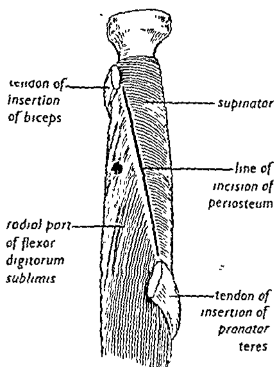


Fig. 93.—Approach to upper third of shaft of radius: line of incision of periosteum along anterior margin of radial attachment of supinator (supinator brevis).

dissection, and the converging radial artery and radial nerve (superficial branch of the radial nerve) are separated. The muscles of the lateral group, namely brachio-radialis (supinator longus), and extensor carpi radialis longus and brevis, are retracted outwards carrying with them the radial nerve (superficial branch of the radial nerve). The pronator teres is retracted inwards with the radial artery (Fig. 92). During the dissection the radial recurrent vessels are secured, divided and ligated. The bone is cut down upon immediately lateral to the biceps tendon, the bicipital bursa being divided (Fig 93) The periosteal incision is continued distally just medial to the front edge of the supinator (supinator brevis), and this muscle is separated in a lateral direction by elevation of the periosteum deep to it with a rugine. The posterior interosseous nerve (dorsal interosseous nerve, deep branch of radial nerve) is carried with the muscle.

Exposure of the lower two-thirds of the shaft of the radius. *Indications.*—The more frequent calls for exposure of the lowest two-thirds of

the radius, or part of it, are as follows: (*a*) operations for open reduction and fixation of fractures of the shaft, (*b*) operations for reconstruction of mal-united fractures, (*c*) osteotomy for deformity caused by mal-union of a fracture or, more rarely, by a developmental anomaly, (*d*) operations for osteomyelitis.

Anatomy.—The lateral of the three surfaces of this bone has no muscle attachments in its lowest two-thirds except the insertion of the pronator teres (pronator radii teres) at about the middle of the bone and that of brachio-radialis (supinator longus) into the base of the styloid process. Consequently, this is the most convenient surface for surgical exposure in most instances. Below the pronator teres insertion the bone is covered, from before backwards, by the tendons of brachio-radialis, extensor carpi radialis longus and extensor carpi radialis brevis. In the lower part these tendons are crossed obliquely from behind, forwards and downwards by abductor pollicis longus (extensor ossis metacarpi pollicis) above and extensor pollicis brevis (extensor primi internodii pollicis) below. These crossing structures partly obstruct the obvious direct approach to the lateral surface of the bone that would otherwise be afforded by separation of extensor carpi radialis longus from brachio-radialis in front or extensor carpi radialis brevis behind. It is therefore usually better to approach the bone from immediately in front of the brachio-radialis, retracting this backwards and taking care not to injure the radial artery, which lies medial to the incision. This is the distal part of the approach to the whole bone described by Henry,* except that he also detached brachio-radialis from its insertion. The radial nerve (superficial branch of the radial nerve) emerges between the brachio-radialis and extensor carpi radialis longus tendons and pierces the deep fascia at about the junction of the middle and lowest thirds of the forearm.

Position.—The patient is placed on his back with the arm abducted and the elbow flexed to a right angle. The forearm lies with its ulnar border resting on a sandbag supported by an arm table.

Operation.—An incision through skin and superficial fascia is made along the radial side of the lowest two-thirds of the forearm, rather nearer the front than the back. With due care of the radial artery, the deep fascia is divided over brachio-radialis, which is retracted backwards with the radial nerve. The periosteum is divided lateral to the insertion of pronator quadratus in the distal part of the wound and to the origins of flexor pollicis longus and flexor digitorum sublimis (radial head) more proximally. The periosteum is elevated from the bone and held so by bone levers, which act as retractors. In cases of sepsis, not involving the lower radio-ulnar joint, care must be taken to avoid its proximally projecting recessus sacciformis.

OPERATIONS FOR RECENT FRACTURES

This subject will be dealt with under the following headings:

(1) Application of skeletal traction by means of (*a*) a pin, (*b*) a wire, and (*c*) skull caliper.

(2) Operation for open (compound) fracture.

* Henry, Arnold K., "Complete Exposure of the Radius," *Brit J Surg*, 1926, xiii, 506

(3) Excision of fragments.
(4) Open reduction of fractures.
(5) Open reconstruction of fractures.
(6) Application of internal splinting.

Osteotomy for mal-union of fractures and bone grafting will be described in later sections.

1. Application of Skeletal Traction

Skeletal traction consists in the application of a pull directly to bone, in distinction from skin traction obtained through material stuck to the skin and from manual traction temporarily exerted by the hands of the surgeon or his assistant.

Indications.—Skeletal traction may be used for the following purposes:

(1) As a means towards reduction and maintenance of reduction of certain fractures, dislocations and fracture-dislocations.

(2) For the separation of inflamed joint surfaces, in order to diminish destruction and to relieve pain and spasm.

(3) Sometimes, after arthroplasty, to preserve an interval between the surfaces of the new joint and so promote subsequent movement.

(4) Similarly after operation for nearthrosis, to prevent telescoping.

(5) As a means of stretching contracted tissues in the correction of fixed deformity.

(6) In the operation of limb lengthening.

Most of these ends may often be served by the simpler and in some ways safer method of skin traction. The following considerations weigh in favour of skeletal traction in any particular case:

(1) If the extent of healthy skin without subcutaneous bony prominences is small, or small in relation to the force to be transmitted.

(2) If the distracting force is to be large, especially if the area of available skin is small.

(3) If traction is to be prolonged. (It is often possible to maintain skeletal traction for longer than skin traction; if this loses its hold, the condition of the skin may prevent further traction by any method; if, on the other hand, a pin or wire used for skeletal traction must be withdrawn, there is no serious obstacle to a change to skin traction, or, often, to the insertion of a new pin or wire at a fresh site.)

(4) If it is proposed to apply a plaster of Paris case to the limb without interruption of traction.

(5) If skeletal traction will allow greater freedom of movement than would skin traction.

(6) If the patient is so thin that skin traction would involve an undue risk of sores or of paresis from pressure over, for instance, the lateral popliteal (common peroneal) nerve.

Complications. *Distraction of the fragments from over-traction.*—

Distraction with consequent delayed union or non-union happens more easily with skeletal traction than with skin traction, because a heavier distracting force can be used, and it is tempting to use it, not merely for restoration of length, but to restore alignment also.

Sepsis.—The dangers of sepsis can be diminished, not only by good aseptic technique, but also by avoiding thermal necrosis about a motor-driven pin, and by avoiding unnecessary damage to the tissues from undue movements of a pin or wire.

Methods.—Methods of applying traction directly to the skeleton are now almost confined to the use of transfixion pins or wires, or of calipers in the case of the skull. Pins are commonly from 4 to 6 millimetres in diameter and have the advantage of simplicity and of not tending to cut out of the bone. They have the disadvantage that sometimes mild infection extends along a pin track, leaving a sinus leading down to an infected area of bone. (This risk is said to be diminished by the use of a stirrup so that the pin can rotate freely within it instead of rotating in the tissues with consequent irritation.) Furthermore, in extraction of a pin, one end, which can be sterilized only chemically, must be dragged through the tissues. With a wire, on the other hand, a sinus is very unlikely, because the thickness, namely from 0·75 to 2 millimetres, is much less, and because one end can be cut off flush with the skin before the rest is withdrawn. Consequently a wire can safely be retained for longer than a pin. A wire, provided it is firmly embedded and does not cut out, is less likely to damage neighbouring structures. Wires have certain disadvantages. The apparatus for insertion is more complicated, and a specialized stirrup is required for maintaining tension. A wire may cut out of bone, but this danger can be diminished by passing it, whenever possible, through the shaft of a bone rather than through the extremity, where cortical bone is scanty, and by using a wire of adequate diameter, namely not less than 1·5 millimetres. The danger of breakage is diminished by the same precaution and by care not to tighten the wire unduly. Both pins and wires readily slip sideways, so that an unsterile portion enters the tissues and one side of the stirrup may press upon the skin. This danger is diminished by strictly transverse introduction and can be overcome by incorporating both stirrup and limb in plaster. Many of the disadvantages of either wires or ordinary pins may be overcome by the use of suitably tempered pins of small diameter ($\frac{3}{32}$ in.).

Skull traction.—Skull traction implies little of the discomfort of head traction by halters. Traction from the zygomatic arches is undesirable, because it involves piercing the masseter muscles. Calvarial traction from near the vertex, where the diploe is thick, has the advantage that the inner table is not penetrated and the apparatus is not in the way when the patient is turned (Crutchfield*), but in

* Crutchfield, W. Gayle (1933), "Further Observations on the Treatment of Fracture Dislocations of the Cervical Spine with Skeletal Traction," *Surg. Gynec. Obstet.*, lvii, 513.
Crutchfield, W. Gayle (1937), "Fracture-Dislocations of the Cervical Spine," *Amer. J. Surg.*, xxxviii, 592.
Crutchfield, W. Gayle (1938), "Treatment of Injuries of the Cervical Spine," *J. Bone Jt Surg.*, xx, 696.

the writer's hands the available apparatus cannot be relied upon to hold its bite. At the cost of penetrating to the dura, it is probably better to take the pull from the temporal bones, with due care to avoid the middle meningeal artery, whose landmarks are well-known. The points or hooklets of skull calipers (McKenzie,* Barton,† Blackburn) or a pair of flexible wire loops (Hoen‡) are inserted through holes made extradurally in the temporal region by means of guarded drills, burrs or small nephines applied under local analgesia.

Chosen sites for insertion of pins or wires for skeletal traction.—In the upper limb, skeletal traction is rarely justifiable. In the lower limb, the usual sites are: (1) the upper part of the tibia, (2) the lower part of the tibia, and (3) the calcaneum (os calcis, calcaneus).

(1) *The upper part of the tibia.*—*The only important structure endangered in this situation is the anterior tibial (deep peroneal) nerve, and the risk of injury to this is slight. The criticism of this* site for traction in femoral and hip conditions is the possibility of injuring the knee by stretching. This complication need not be feared if these precautions are taken: (*a*) the knee is kept flexed, (*b*) it is protected from lateral strain, (*c*) the distracting force is reasonable, and (*d*) it is not maintained unduly long (e g. more than three months or after a fractured femur has united).

(2) The lower part of the tibia.—This site, through the diaphysis, has been advocated and practised by Watson-Jones because it avoids the disadvantages of the calcaneum. The lower part of the tibia, even when applicable, has disadvantages of its own, namely transfixion of the anterior compartment of the leg and poor adaptation to plastering with traction maintained.

(3) The calcaneum.—The disadvantages of this site are that the foot tends to stiffen and that traction is exerted through joints.

A note on the lower part of the femur as a site for transfixion.—The disadvantages and dangers of this site, closely associated with the synovial membrane of the knee, are still insufficiently recognized. The suprapatellar pouch laps round the femur for more of its circumference than is commonly supposed, and is endangered, however careful the operator. If the synovial membrane is not actually pierced, with the consequent risk of septic arthritis, the proximity of a foreign body promotes stiffness. A wire may cut out, and, if it does so, inevitably enters the joint, which has been known to become infected in this way. Although transfixion of the femur might seem at first sight to allow the freest knee movement, in fact nailing the aponeurosis to the bone is a serious deterrent to movement. In short, the lower part of the femur is a bad site for transfixion and should

* McKenzie, Kenneth G (1935), "Fracture, Dislocation, and Fracture-Dislocation of the Spine," *Canad med Ass. J*, xxxii, 263

† Barton, Lyman G (1938), "The Reduction of Fracture Dislocations of the Cervical Vertebrae by Skeletal Traction," *Surg Gynec Obstet*, lxxvi, 94

‡ Hoen, Thomas I (1936), "A Method of Skeletal Traction for Treatment of Fracture Dislocation of Cervical Vertebrae," *Arch Neurol Psychiat, Chicago*, xxxvi, 158

be reserved for such rare circumstances as a broken femur with ruptured ligaments at the knee.

Surroundings for operation.—The insertion of either a pin or a wire calls for strict care to avoid sepsis, but can readily be performed with the patient in bed in a ward if necessary.

Anæsthesia.—General anæsthesia is perhaps preferable to local analgesia in suitable cases for these reasons: (*a*) the general anæsthetic is more certain to relieve pain at the site of operation; (*b*) it relieves

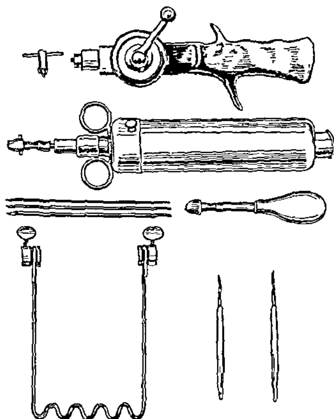


Fig. 94.—Instruments for the application of skeletal traction by means of a pin.

also pain which may occur at the site of fracture from movements of the limb, and (*c*) the patient is excused being a conscious party in what to him may be a revolting procedure. The patient's general condition or the nature of the injury may demand local analgesia, almost invariably so for skull traction.

Insertion of pin for skeletal traction. Instruments (Fig. 94).—Probably the most suitable pin is that of Steinmann, which has one end pointed (preferably triangular in section) and the other squared in adaptation to the socket of a handle. With this it can usually be driven easily through cancellous bone but with difficulty through cortical bone, so that a mallet is often brought to bear. This roughness can be avoided by the use of a motor, with appropriate chuck, or an

efficient hand-drill. A tenotome or small scalpel is required for puncturing the skin. A stirrup, suited to the length of the selected nail, also is sterilized. Weights, cords, spring balance, etc., should be prepared ready for use. If a Thomas's splint is to be used, it should have a large enough ring to pass over the pin, or alternatively should be applied before the operation is begun.

Operation.—The bony landmarks having been determined, the prepared area of skin is drawn proximally with the operator's left thumb and forefinger or by the assistant. A skin incision is made just large enough to admit the pin. This is driven through the bone strictly at a right angle to the long axis of the limb. Pledgets of cotton wool may be used for dressing the sites of entry and exit, but

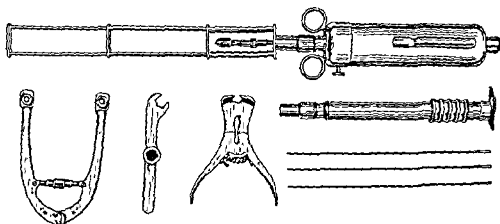


Fig. 95.—Instruments for the application of skeletal traction by means of a wire.

possibly it is best to leave them exposed; if covered they tend to become moist, especially if sealed, and, should the pin slip, fragments of dressing may be drawn into the tissues.* The stirrup is applied, and splinting and traction are carried out in the usual manner.

Comment.—If the pins are inserted by a motor care must be taken not to sear the bone.

Insertion of wire for skeletal traction. Instruments (Fig. 95).—The steel piano wires, usually known as Kirschner's wires, are pointed at one end and preferably flattened at the other; they should be at least 1·5 millimetres in diameter. The most effective driving mechanism is an electric motor fitted with an appropriate chuck and provided with a telescopic frame to minimize bending of the wire, alternatively a guide may be clamped to the limb A stirrup is needed which is capable of rendering the wire taut and holding it so; most stirrups require an appropriate spanner, and some a separate wire-tightener. Nippers are used for cutting the wire; those supplied by some makers are ineffective.

* The late General Editor strongly advocated the application of "Bipp", renewed fortnightly, in the prevention of infection round transfixion pins and wires.

Operation.—As in using a pin, the skin is drawn proximally. The wire is driven through the bone at right angles to the long axis of the limb and is disengaged from the chuck. Dressings may be applied about the wires at the puncture holes. The stirrup is applied and [illegible] traction [illegible] The ends [illegible]

Transfixion pin and ambulatory treatment.—One or two transfixion pins are sometimes inserted above as well as below the fracture and are incorporated in plaster, so that the patient is free from traction weights and can walk about. This method has often been used for a fracture of the tibia, but there is a danger that the pins will prevent close contact of the fracture surfaces when absorption of these begins.

Ambulatory fracture apparatus on similar lines has been much used in America, but has found little favour in this country (except for certain fractures of the mandible). Two pins are introduced at an angle to one another above the fracture and two below. They pierce only one side of the limb, but they transfix both near and distant cortices of the bone. The projecting ends of each pair of pins (or half-pins, as they are sometimes called) are held in a clamp, which, with the two pins, is called a transfixion unit. The two units are linked by a distraction bar, by means of which they can be distracted or approximated. Provided such an apparatus is used to compress the bone ends together and not to distract them, rapid union may be achieved. The method has been used for fractures of such bones as the femur in the hope of encouraging early movement of the knee, but it is optimistic to expect anything but the reverse from an apparatus that nails the thigh muscles to the femur. It has an important place in the treatment of some mandibular fractures, and possibly has some place in the treatment of certain tibial fractures.

Transfixion pins in operations other than for fracture.—In arthrodesis of the knee, a pin through the femur and one through the tibia are often linked by approximating turnbuckles which lock the raw surfaces together and accelerate union. An alternative practice of passing pins across the site of an arthrodesis is usually to be condemned, because two pins at an angle are necessary for firm fixation, and they prevent impaction. This criticism does not apply to the use of one flanged nail.

Subtrochanteric osteotomy is sometimes preceded by the insertion laterally of pins above and below the proposed site of division. The parts of the pins projecting through the skin help the production and maintenance of a correct position of angulation and rotation.

2. Operation for Open (Compound) Fracture

Indications.—Unless the skin opening is a puncture only, early operation is imperative for major open fractures. The procedure

described is for such a fracture in a limb. Clearly it would be inapplicable, for instance, to a crushed terminal *phalanx of a hallux*, perhaps the commonest of open fractures, in which involvement of cancellous bone with great recuperative powers requires much simpler measures.

Pre-operative treatment.—In severe injuries, general treatment is paramount. Rest to the local lesion is part of general treatment, and the patient is preferably splinted before he is moved. Apart from this and perhaps the application of an antiseptic pad with the pressure necessary to arrest hæmorrhage, the less avoidable disturbance the better Once the patient is upon a stretcher he should not be moved off it till he reaches the operating theatre. If visceral complications are unlikely, morphia should be given early, with due safeguards against unwitting repetition. If important hæmorrhage has occurred, the loss must be remedied. Excessive fluid by mouth tends to be vomited during a subsequent anæsthetic. Although clinical examination and radiography are important, they should be carried out with the least possible disturbance, and the patient should not be unnecessarily disrobed. Operation must be delayed till primary shock has passed. Quarter-hourly or half-hourly pulse and blood pressure records assist in the assessment of progress, the blood pressure cuff being left in place throughout.

Instruments.—Unsterile scissors and scalpel for removal of clothing. Razor, and appurtenances for cleansing the skin. Soft tissue foundation set, with supplementary dissecting forceps, scalpels and scissors. Bone cutting instruments. strong bone cutting forceps, osteotomes and mallet. Apparatus for external fixation: plaster of Paris and accessories; splints; traction apparatus, including, if necessary, transfixion wires or pins and their accessories. Syringes, charged with antitetanus serum, and with penicillin; serum needles to fit. Penicillin and sulphanilamide powder in sterile insufflator, if available. Hot saline solution.

Operation.—General anæsthesia is preferred. Under the anæsthetic, the patient's clothes are removed with the least possible disturbance of the limb, the wound is covered with a swab and the surrounding skin is thoroughly cleansed and shaved. If possible, a pneumatic tourniquet is applied, it is inflated after the limb has been exsanguinated by elevation and momentary Esmarch bandaging, which should not be allowed to constrict the site of the wound and fracture. If skeletal traction is likely to be needed, it is often best to insert the pins or wires at this stage. The skin margins are excised, for a minimal width, and the wound is extended as necessary. The deeper parts are similarly dealt with, fascial planes being freely opened. Any torn or crushed soft tissues, foreign bodies or completely detached fragments of bone are removed Bony surfaces that are obviously soiled are taken off as slivers with osteotome and mallet. Attached spicules of bone not

obviously soiled and important structures, such as large arteries and veins, are carefully preserved. If stable reduction of the fracture by manipulation under vision through the wound is possible without undue further injury, that is done. The tourniquet is released. Any obvious ischæmic tissues that remain are excised. Hæmostasis is secured, as much as possible by twisting rather than ligation, and by gentle hot lavage and swab pressure. After penicillin insufflation the skin is closed with interrupted sutures, without tension. Undue tension can often be relieved by counter incisions at a distance. If closure is impossible by such an expedient, flaps or pedicle grafts should be used, or, if all else fails, a split skin graft. In flaying injuries, ischæmic flaps of skin must not be replaced without previous denudation of fat, when they can be treated as grafts. After the wound has been dressed, the fracture is treated as though a closed (simple) fracture. If a plaster case is applied, it should be split longitudinally; a window may be cut, provided (*a*) it does not prejudice fixation of the limb or strength of the plaster, (*b*) pressure is applied over it, and (*c*) the limb is elevated. While the patient is still anæsthetized he is given intramuscular injections of tetanus anti-toxin (3,000 international units, equivalent to 1,500 American units) and penicillin (say 100,000 Oxford units as an initial dose).

Comments.—In a recent open fracture the following are important in the order named. (1) the general condition of the patient; (2) the circulation in the part and therefore its viability; (3) defence against infection, including (4) complete skin cover; (5) the fracture; (6) injury to other structures Although injuries to such structures as nerves and tendons may affect the ultimate usefulness of the limb much more than the fracture does, the fracture usually takes precedence of them in treatment.

When a limb is run over it may be ground between the road and a braked wheel; the consequent wide extent of non-viable tissue is readily overlooked (Slack*, Henderson and Rouillard†).

The great safeguards against infection are (*a*) complete exposure [illegible] he whole of the deep wound with removal [illegible] bodies, (*b*) complete skin closure without [illegible] post-operative rest, (*e*) attention to the general condition of the patient—sleep, fluids, hæmoglobin, diet, etc.

In the after-treatment the limb is elevated, and its circulation carefully watched. Ice bags are a much neglected aid, they diminish pain, swelling and the risk of ischæmic necrosis. The local treatment is like that of a closed (simple) fracture, except that (*a*) it may be wise to postpone some exercises till the cutaneous wound is healed and (*b*) continuous traction should be moderated more than ever if there is loss or division of muscles or tendons, because in such circumstances it may promote deformity, and easily causes distraction.

* Slack C C (1952), "*Friction Injuries Following Road Accidents,*" *Brit med J.*, ii, 262.
† Henderson, R S, and Rouillard, L M (1953), "Types of Injury in Run-Over Lower Limbs," *Proc Roy. Soc. Med*, xlvi, 350

The word " débridement ".—*This French word means " unbridling ",* and it is correctly used for the free opening up of a wound. Confusion presumably with the unrelated word debris, led to its use in America for scavenging or the toilet of wounds, namely excision with removal of all avascular tissue and foreign bodies, and even for the scavenging of an arthritic joint. The word has returned to these shores with this new and erroneous sense. The consequent ambiguity demands, unhappily, that this word, so picturesquely coined, should be banned from the surgical vocabulary—*a good word outraged!*

3. Excision of Fragments

In cases of recent fracture, detached fragments should rarely be excised: (1) unless the fragment, or fragments, are of little functional importance and would be likely to interfere with the future function of a joint, (*a*) by causing permanent bony block to movement, as in an extensive crush fracture of the radial head, (*b*) by forming a loose body, as in a segmental fracture of the radial head with much displacement of the fragment, (*c*) by disturbing the articular surface in such a way as to be likely to promote osteo-arthritis, as in many cases of comminuted fracture of the patella; (2) unless a fragment projects beneath the skin, so as to menace its integrity, and cannot be displaced by conservative methods; (3) unless, in an operation for an open fracture, a small fragment is found completely untethered.

4. Open Reduction of Closed (Simple) Fractures

Indications.—Open reduction is required in cases of fracture in which the raw surfaces cannot be brought into sufficient apposition by ordinary methods; either because there is no means of overcoming the pull of muscles attached to one fragment or both, as happens for instance with some fractures of the olecranon and patella, or with separation of the internal humeral epicondyle; or else because muscle or fascia intervenes between the fragments, as in some cases of fracture of a long bone, such as the femur, one fragment of which may be driven through the quadriceps. Occasionally a fragment such as the medial epicondyle of the humerus, still attached to soft tissues, becomes trapped in a joint and must be released from this before being restored to its proper position. More commonly a quite loose fragment, such as a part of the head of the radius, is shed into the cavity of a joint; such unattached fragments usually demand removal as described in the chapter dealing with operations on joints.

An open operation should not be undertaken when skilfully applied conservative methods would be expected to produce satisfactory results. Some of the operations tend to be unexpectedly difficult; most add to the duration of convalescence, and nearly all involve an added risk to the patient. Open reduction should never be carried out in unsuitable surroundings. The tendency towards operation will vary inversely with the skill of the surgeon in conservative treatment

and directly with his insistence on anatomical perfection. This is essential for good function, or even for union, after fractures at certain sites and at certain ages, but not so at others.

The parts where fracture most often needs open reduction are the patella, olecranon, capitulum, medial epicondyle of the humerus, and shafts of the radius and ulna.

Time to operate.—Operation is easiest within a few hours of the injury, but it is possibly safer to wait at least a couple of days for the local defences to become mobilized. Operation should be performed within ten to twelve days, after which it becomes difficult, fragments can no longer be interlocked and the risk of delayed union or non-union increases. In some fractures of both bones of the forearm and possibly some fractures of the capitulum, it may be right to attempt closed reduction first, but, if this fails, an early decision should be made in favour of operation.

Operation for reduction and suture of fractured patella. Indication.—Transverse fracture of the patella with wide separation of the fragments. This separation implies tearing of the quadriceps expansion over and to either side of the patella, a serious injury to the extensor mechanism of the knee, and it is for repair of this that the operation is undertaken. Indeed, provided the aponeurosis is sutured, there is no real necessity to suture the patella itself; but to do so may provide more accurate apposition and a firmer hold, so that this is the operation here described.

If, in a transverse fracture, the fragments are not materially separated, the quadriceps expansion must be intact and no operation is required

In comminuted fractures also, the aponeurosis is intact, but operation may be demanded by irregularity of the surface presented to the femur by the fragments, which cannot usually be overcome satisfactorily except by excision; this is described in the appropriate place (page 306). Otherwise there is no call, in recent cases of fracture, for excision of the patella, which leaves the knee without a normal shield and with diminished final extension power. Sometimes a smooth posterior surface can be attained by the removal of one or a few fragments instead of all fragments.

Special instruments.—Sharp awl (with sub-terminal eye), Volkmann's spoon, Kocher's forceps, and suture material—stout chromic catgut for the aponeurosis but preferably stainless steel wire for the patella. Plaster of Paris outfit.

Operation.—A tourniquet is best omitted because it tends to bind down the quadriceps and consequently prevent easy traction on the upper fragment of the bone. An antero-lateral incision, concave medially is probably best, as being away from the pressure points of kneeling, giving good access to the collateral parts of the quadriceps expansion and not dividing the infrapatellar branch of the saphenous nerve. The margins are reflected enough to reveal the edges of the

torn aponeurosis, any flap hanging between the fracture surfaces being withdrawn. The blood clot between the fragments and that accessible in the joint is gently swabbed away, and any remaining adherent to the raw bone surfaces is removed by a Volkmann's spoon. The fragments are drilled with a sharp awl, and the suture material is passed; the upper fragment is drawn down and approximated accurately to the lower fragment by traction on Kocher's forceps attached to the neighbouring aponeurosis; and the suture is secured (Fig. 96). The lateral expansions and the aponeurosis over the patella are sutured. Hæmostasis having been secured the wound is closed without drainage. A compression bandage is applied over dressings and cotton wool. A plaster of Paris posterior splint is applied.

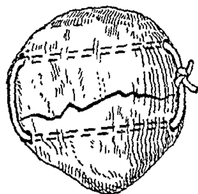


Fig. 96.—Diagram of a method of suturing fractured patella.

After-treatment.—Radiographs are taken. Quadriceps contractions are started as soon as possible, but flexion exercises and walking are deferred for three weeks. A splint may be worn for walking until flexion beyond a right angle has become possible. Unless this precaution is taken a stumble may be disastrous. The best form of splint is one of plaster of Paris moulded to the shape of the limb; the splint should cover the posterior half of the circumference of this and should extend from below the fold of the buttock to the upper part of the tendo Achillis.

Fascial suture.—Gallie and LeMesurier* described suture with a free graft of fascia lata (femoris) in old cases, and Groves† recommended a pedunculated strip of fascia lata in old and recent cases (Fig. 97).

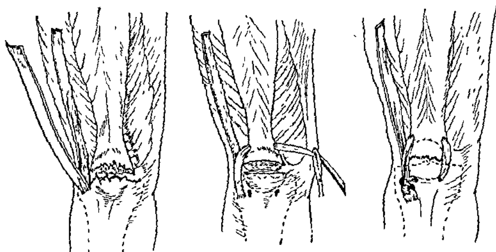


Fig. 97.—Fascial suture of patella (Hey Groves).

* ... lantation of the Fibrous Tissues in the Repair of Anatomical

† *Modern Operative Surgery*, 3rd edn, edited by G. Grey ... Cassell and Company, Ltd

Operations for reduction and suture of fractured olecranon. Indications.—Fractures of the olecranon should preferably be treated by open operation, provided there is important displacement and the patient's general condition allows. In border-line cases in elderly people it should be remembered that an un-united fracture of this process is compatible with fair function in spite of some limitation and weakness of extension. A compromise is offered by excision of the detached fragment and reattachment of the triceps tendon; this hardly less extensive operation has been popular in recent years. A large olecranon fragment often implies a potential fracture-dislocation, and should be reattached, not excised.

Instruments.—As for reduction and suture of fractured patella.

Position.—The patient is placed on his face with the abducted upper limb lying on a table over a sandbag with the elbow extended.

Operation.—No tourniquet is used, as binding down the triceps makes apposition of the fragments difficult. A superficial curved incision is made over the inner part of the back of the elbow, and the ulnar nerve is defined. The fascia and periosteum are incised over both margins of the back of the olecranon and the muscles are separated from its sides with the periosteum The blood clot between the fracture surfaces is removed with swabs and Volkmann's spoon. With a sharp awl a transverse hole is drilled through each fragment, and a suture is passed. By means of Kocher's forceps, attached to the aponeurosis on either side, the proximal fragment is brought down accurately to the distal, and the suture is secured. If the proximal fragment is small, it need not be drilled and the suture can pass through the triceps attachment instead of the bone. Besides the O-shaped suture described, Watson-Jones* advocates an additional suture in the form of a figure-of-eight whose loops traverse the holes and whose St. Andrew's cross (×) lies over the back of the olecranon preventing its becoming angled backwards (Fig. 98). The aponeurosis is repaired, and the wound is closed without drainage. Dressings,

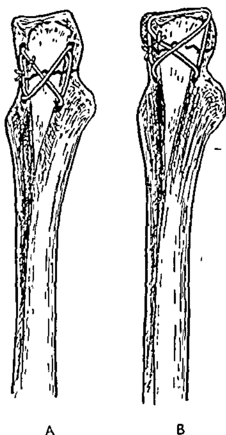


Fig. 98.—Diagram of method of suturing fractured olecranon, to prevent backward angulation (Watson-Jones).

A, Large proximal fragment; sutures transfix it B, Small proximal fragment, sutures transfix triceps tendon

* Watson-Jones, R, *Fractures and Other Bone and Joint Injuries*, 1940. Edinburgh E. & S Livingstone, 344

cotton wool and a bandage are applied, and the elbow is splinted with a plaster of Paris gutter splint in a position of slight flexion.

After-treatment.—Radiographs are taken. The splint is removed and active movements are begun as soon as the wound is healed and the stitches are out. As in all conditions involving the elbow joint, massage and passive movements must be avoided.

Open reduction of fracture-separation of the capitulum.—Fracture-separation of the capitulum is a fairly common injury, usually in childhood. The separated portion consists of a part of the trochlea, which may be entirely cartilaginous, most of the capitulum and often a small angle of the diaphysis (Fig. 99). The condition is frequently unrecognized because of ignorance of the radiological appearances of the lower end of the humerus in children, failure to examine radiographically the normal elbow as well as the damaged one, and the inadequate attention given to this injury in textbooks. The fragment often remains attached at its upper angle to the shaft by periosteum and rotates upon its soft tissue attachments, coming to lie on the inner side of the arm and no longer within the joint. It can be felt subcutaneously in the new position, and there is undue lateral mobility of the elbow. Radiological examination shows the greater part of the capitular nucleus lying away from the joint, often with a small piece of diaphysis attached. Failure to recognize the condition and replace the fragment leads to cubitus valgus, undue laxity of the elbow and often late ulnar paralysis.

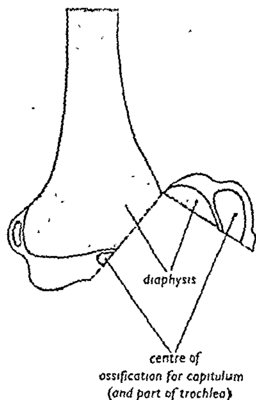


Fig. 99.—Diagram of fracture-dislocation of the capitulum—an injury requiring open reduction nearly always. (Ossified parts shaded dark.)

Position.—The patient is placed on his back with the arm abducted and medially rotated, the elbow resting in the semi-flexed position on a sand-bag supported by an arm table.

Operation.—An axial incision is made over the outer aspect of the lower end of the humerus. The forearm is adducted, and the cavity from which the fragment has come is sponged free from clot, the fracture surface being cleaned with a Volkmann's spoon. The fragment is rotated and coaxed back into the joint so that its raw surface

is in accurate apposition with that of the lower end of the humerus. Usually no internal fixation is needed, but a few catgut sutures may be inserted if necessary. The wound is closed without drainage and dressed. A plaster splint or case is applied in such position as is found most readily to keep the fragment in place; that will usually be at about a right angle, or rather less flexed.

After-treatment.—Radiographs are taken. The wound is either left alone for six weeks, or alternatively the plaster may be removed after about ten days, the stitches removed without movement of the elbow and an unpadded plaster substituted. Fixation should continue for six weeks, after which the patient is allowed to regain movements by his own efforts. No rubbing or stretching should be given.

Note on fracture of the capitulum in adults.—In adults a different kind of fracture of the capitulum may occur, in which its front half is sheared off. The usual treatment is removal of the detached fragment, and Watson-Jones* has drawn attention to the bad results, which he ascribes to adhesion of the capsule to the remaining raw area of bone. He has advocated replacement of the detached fragment; but this is avascular, and it is doubtful whether the results are any better.

Open reduction of fracture-separation of the medial epicondyle of the humerus.—The injury is an epiphyseal separation and may complicate obvious dislocation of the elbow; probably all or most cases are caused by transient dislocation, and in consequence the fragment may be trapped within the joint. If this happens the fragment must be freed and fixed in its proper place; otherwise there will be gross disturbance of joint function. If it is outside the joint but much separated an operation should be performed for suturing it into place; otherwise much undue lateral mobility of the elbow may remain, because the medial (internal lateral) ligament is attached to the fragment, and late ulnar paralysis will be a likely sequel. If the displacement is only slight, however, it is unlikely to be rectified by operation because the pull of the pronator and flexor muscles is difficult to overcome completely. Moreover, in spite of a small gap, union takes place and perfect function is restored The epiphyseal disk of the medial epicondyle is commonly obliterated, but growth of the rest of the lower end of the humerus tends to restore the epicondyle to its proper relative position.

Position.—The patient is placed in the dorsal position with the arm abducted and laterally rotated, the elbow resting on a sand-bag on a side table.

Operation.—The ulnar nerve is exposed, and forward transposition is carried out (*see* p. 526). The raw surfaces of bone are cleaned with a Volkmann's spoon and brought into contact behind the transposed ulnar nerve by means of silk or catgut sutures, the muscles being relaxed by flexion and pronation of the forearm. The sutures should

* Watson-Jones, R., *Fractures and other Bone and Joint Injuries*, 1940 Edinburgh· E & S. Livingstone 340.

pass through soft tissue only; otherwise the main epiphyseal plate may be damaged. The wound is closed without drainage; dressings, cotton wool and a bandage are applied, and the tourniquet is removed The elbow is fixed in a plaster trough in a position of flexion and pronation.

After-treatment.—Radiographs are taken. Fixation should continue for six weeks, but it is an advantage at the end of ten days to remove the splint, take out the stitches and fix the limb in an unpadded plaster of Paris case in a position of slightly less flexion. Mobility is regained by active movements only.

Open reduction of fractures of the radius and ulna.—In spite of improved methods of closed treatment there are still cases of fracture of the shaft of the radius or ulna, and particularly fractures of both, which require open reduction. This should rarely be performed in children under the age of about twelve years; in them slight deformity after efficient closed manipulation is of small moment and does not warrant the hazards, such as they are, of a difficult open operation. A surgeon undertaking treatment of these fractures must make up his mind about operation early enough for this to take place not later than the tenth day after fracture, because the raw ends of the fragments become rapidly rounded off. By the fourteenth day operation may have become extremely difficult.

Some forearm fractures, and especially fracture-dislocations and fracture-subluxations need open operation, *not* for reduction, but for its maintenance by internal fixation. This is considered in the section on internal splinting.

Operation.—The shafts of the radius and ulna are separately approached as already described. By means of traction and perhaps judicious angulation the fragments are brought end to end and made to interlock, care being taken to insure that they do so accurately without rotation deformity. A test is made to find in what position of the forearm the fragments most readily stay in place. The principal assistant or the surgeon himself should hold the fingers and arm securely while the wound is closed and dressings, cotton wool and plaster are applied, the pneumatic tourniquet is removed and the plaster of Paris case is completed to extend to the axilla from the metacarpal necks.

After-treatment.—Radiographs are taken to confirm the position in plaster. Finger and shoulder movements start. After three weeks the plaster is removed, the stitches are taken out and an unpadded plaster of Paris case of the same extent is reapplied. It is retained for a further five weeks. It is then removed, a clinical and radiological examination is carried out, and, if these prove satisfactory, free movements are started. Usually, however, further immobilization is required because of the danger in adults of non-union and in children of refracture.

5. Open Reconstruction of Fractures

There is a stage in the establishment of mal-union of a fracture at which the callus is too firm to allow closed correction by manipulation, but is still soft enough to allow open correction without resort to osteotomy. For instance, in mal-union of a Colles fracture, between about the sixth and twelfth weeks, it is possible to scrape away callus from the lower end of the radius with an osteotome, and to lever the bones into reasonably good position. After closure of the skin, plaster of Paris is applied from the metacarpal necks to the upper arm, with the hand and wrist flexed, adducted and pronated.

6. Application of Internal Splinting

Fracture surfaces may be held in position by various mechanical means, such as sutures of catgut, kangaroo tendon, thread or wire; metal bands, nails, pegs, staples, screws, or plates attached by screws. Bone grafts are dealt with in a separate section. Internal splinting must often be supplemented by external splinting such as plaster of Paris.

Indications.—(1) Cases in which *apposition* of the fracture surfaces cannot be maintained by conservative measures, e.g. fracture of the patella or the olecranon with separation, some cases of fracture of the radius and ulna, the medial malleolus, etc.

(2) Cases in which *maintenance of reduction* would be difficult or impossible by external splinting Open reduction and internal splinting are imperative in an oblique fracture of the lower part of the radial shaft with subluxation of the radio-ulnar joint, and in fracture of the upper part of the ulnar shaft with dislocation of the radial head (Monteggia fracture). Internal splinting is often needed to maintain open reduction in fractures of both forearm bones. Open reduction and screwing is the only reliable method of treating fracture-subluxation of a major joint caused by the separation of a wedge with a consequent step in one articular surface, for instance a wedge fracture of the lower end of the tibia.

(3) Cases in which external splinting offers insufficient *immobilization* to secure union—trans-cervical fracture of the femur.

(4) Cases in which the *restraint of external splinting would endanger the patient*—the most important reason for internal fixation of trans-cervical fractures of the femur.

(5) Cases of *multiple fracture*, e.g. shaft of femur and shaft of tibia.

(6) Cases in which the surgeon may consider that the advantages of *early mobilization of the patient and the injured member* outweigh the disadvantages and dangers of an operation for internal fixation, e.g. per-trochanteric fractures of the femur.

(7) Apart from fracture treatment, internal splinting is sometimes used as an *adjunct to other operations*, e g. in arthrodesis of the hip.

The time for operation.—For its satisfactory performance the application of internal splinting should usually take place relatively early,

preferably not later than the tenth day; otherwise the fracture surfaces become rounded off so that they cannot be accurately interlocked and union may be greatly or indefinitely delayed. For this reason, among others, internal splinting, except with grafts, should play little or no part in the treatment of non-union of fractures. It must be conceded that reduction, with the use of internal splinting, has been followed by union previously long delayed, but in such cases it is the bringing of separated parts into apposition, and their maintenance, that enables union to occur, rather than any special merit in internal fixation as such.

Disadvantages of internal fixation.—The application of internal fixation always implies a *major operation*, sometimes a severe and difficult one.

Danger of sepsis.—Even nowadays this risk from the introduction of foreign bodies cannot be ignored, as any considerable series of cases will show. Internal splinting of bones should not be undertaken except in suitable surroundings and with every reasonable refinement of aseptic technique. Because of the danger of sepsis in the presence of a foreign body—even a relatively inert one—the present writer believes that *open fractures should be considered outside the scope of internal splinting*, although the venture often succeeds.

Delayed union and non-union.—The use of foreign bodies, the stripping of tissue required for their application and the gap which may develop between the bone fragments are probably all factors that tend to promote delayed union and non-union and that cannot be wholly controlled by good technique.

Loosening of internal splint.—This has been partly, but not wholly, overcome by the use of better material, better mechanical methods and perhaps improved asepsis. In pathologically soft bone, screws and nails will not hold at all, and internal splinting is therefore generally *inapplicable in porotic conditions*, such as Paget's disease in some instances.

Breakage of fixation apparatus.—This has diminished with improved design and manufacture, and improved appreciation of the mechanical strains imposed.

Weakening of the bone.—This is inseparable from some forms of fixation. It is particularly apparent in children, in whom a foreign body may interfere with growth in girth of a long bone, so that fracture through the site of an old plating operation has often occurred *Internal splinting of fractures in children is rarely, if ever, justifiable.*

Interference with longitudinal growth.—In children the application of foreign bodies near the ends of the long bones may cause perforation of an epiphyseal plate and consequent interference with growth, so that shortening, deformity, or both, may occur.

Methods of internal fixation. Sutures.—Fixation with sutures passed through drill holes or through the soft tissues has been sufficiently mentioned in dealing with the open reduction of fractures. Encirclement with wires or metal bands is almost obsolete and does not need to be described.

Screws.—These may be used for reattachment of fragments—in fracture of the olecranon, for instance—but are more damaging than sutures and are therefore less desirable unless a particularly close fit is desired. An example of such fixation is the popular use of a screw in fractures of the medial malleolus after removal of any periosteum that may have dropped between the fragments. Often this operation may be unnecessary, because non-union is of doubtful consequence unless the fragment is large enough to involve the horizontal part of the ankle joint. Apart from the attachment of plates, screws are most useful in oblique fractures with over-riding, as a substitute for continuous traction. In spiral fractures of the shaft of the tibia, for instance, transfixion with a single screw is sufficient to maintain length provided its mechanical imperfections are made good by external splinting (and preferably a second screw, if possible without splintering). Reference has been made to the use of a screw in similar fractures at the ends of bones with separation of a wedge. Screws can be used also in bone shortening, or in " step-cut " operations for non-union in the upper limb.

A special large lag-screw is sometimes used instead of a tri-fin nail in fractures of the surgical neck of the femur in order to compress the fragments together.

Besides their direct application to fractures and their use in attaching plates and bone grafts, screws are occasionally used *temporarily* for maintenance of reduction of dislocations and fractures. Fracture-dislocations of the ankle sometimes involve a diastasis of the lower tibio-fibular joint which it is very difficult or impossible to hold reduced by any means except temporarily screwing the bones together at a level proximal to the joint. Similarly the clavicle may be screwed temporarily to the coracoid in recent cases of acromio-clavicular dislocation.

Screws for most surgical purposes should be of the engineer's pattern, rather than carpenter's, that is cylindrical, threaded right up to the head, and self-tapping. They should be of a single standard gauge, but in a large number of lengths. Preferably those for cancellous bone should have a larger thread than those for cortical bone. The usual standard thickness, measured between the depths of the thread, is $\frac{7}{64}$ in. so that the screw will cut a thread for itself and remain firmly fixed in a hole made by a $\frac{7}{64}$-in. drill (in cortical bone, a $\frac{1}{8}$-in. drill is often better). In order to obtain an initially tight fit between bony surfaces by screwing, it is necessary that the fragment penetrated first should be drilled with a larger hole than that penetrated second. The Morse drills should be of exactly appropriate gauge, and should preferably have their cutting part confined to the terminal $\frac{1}{2}$ in.

(Fig. 100); otherwise drill holes will almost certainly be tapered, which is often undesirable. To diminish the tendency for the screwdriver to slip from the heads of the screws, these should preferably have a central depression to engage a corresponding tongue on the screwdriver (Sherman's screws, Fig. 101A) or a cruciform slot requiring a screwdriver of similar section (e.g. Collison's screws, Fig. 101B).

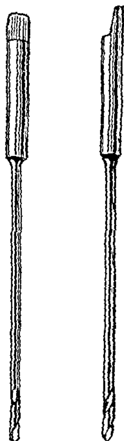


Fig. 100.—Drills. The cutting part is preferably short, as shown here, to avoid making tapered drill holes.

Plates. A bone plate is the standard internal *splint for a transverse fracture of the shaft of a bone.*

Bone plates must be strong enough for the work they have to do, tough enough to be bent and long enough for an adequate purchase. The drill holes, which should usually be six in number, should take the screws freely They should preferably be oval (Burns's plates) or replaced by slots (Egger's plates), to allow final impaction of the bone fragments after the screws have been inserted but not tightened. Failure to secure close apposition, aggravated by subsequent absorption at the bone ends, is an important source of delayed union and non-union after bone plating. The screws should transfix the distal cortex as well as that adjacent to the plate; that is, the length of their shanks should exceed the width of the bone by the length of their points.

Nails and pegs.—Small nails and pegs may be used to re-attach fragments. Elementary carpentry dictates the insertion of not less than two, at an angle with each other. Though convenient, they have the defects of screws without their *efficiency.*

"Beefbone" pegs have little advantage over vitallium or stainless steel nails because absorption is very slow.

Large intramedullary "beefbone" pegs were at one time popular for the internal splinting of fractured shafts of long bones, but they have been abandoned because of their mechanical imperfection in controlling rotation and angulation and their interference with endosteal callus formation. Similar *objections* have held with the intramedullary use of such *substitutes as*

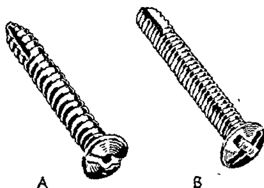


Fig. 101.—Screw heads with devices to prevent slipping of screwdrivers.

Kirschner's wires, Steinmann's pins and the like. These have now been replaced for this purpose by the intramedullary nails of Kuntscher, which will be referred to again. They have the mechanical shortcomings of intramedullary bone pegs in much smaller degree but appear to interfere equally with endosteal callus formation.

The treatment of the patient with a trans-cervical fracture of the femur was transformed by the introduction of the Smith-Petersen nail, which has saved the lives of many and restored some to useful activity. This subject is discussed more fully later. Multiple slender nails have been used for the same purpose.

In order to adapt a similar principle in circumstances less suitable for nailing, such as per-trochanteric fractures, nails of various types have been combined with plates—*nail-plates*.

Metals used for internal splinting.—" Beef " bone and autogenous bone, in the form of grafts, may be used for internal splinting, but only metal is suitable for the mechanical strains usually involved. The metal chosen should not only be sufficiently tough and capable of

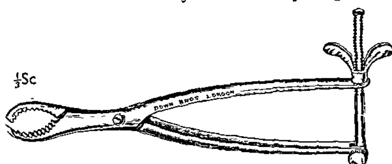


Fig. 102.—Bone-holding forceps with clamp (Hey Groves's, cf. Fig. 83, p. 238).

being worked into suitable forms at reasonable cost, but it should excite as little reaction as possible in the tissues. In practice the choice has been reduced to two, either a *suitable* stainless steel* or a suitable non-ferrous alloy.† Of these, stainless steel—though probably slightly less stable—is usually preferred in this country, as being more easily worked, possibly more dependable, more readily available and cheaper. The choice between the two is unimportant, but it is imperative that only one metal should be used for one case. Two different metals in the same patient form, with the tissue fluids, a Galvanic battery, with consequent electrolytic erosion of one of them.

Operation for bone suture.—This has been sufficiently described under open reduction of fractures (p 261 onwards).

Operation for screwing a fracture of the shaft of a long bone. Special instruments.—In addition to the instruments required for exposure of the part, the following are required: Volkmann's spoons for clearing the bone ends; Lane's bone-holding forceps (Fig 83), including clamp forceps (Fig. 102); standard screws as described

of various lengths about equalling the diameter of the bone; drills appropriate to the screws (usually $\frac{7}{64}$ in., $\frac{1}{8}$ in. and $\frac{9}{64}$ in.); *hand or motor drillstock to take the drills; screwdrivers appropriate to the screws*—one incorporating a screw holding device (Fig. 103); failing this type of screwdriver, *screw-holding forceps; measuring scale;* perhaps also a special device for measuring the length of the drill holes.

Operation.—The site of fracture is exposed, as described in the section on exposure of the shafts of the long bones. With as little disturbance of their blood supply as possible, the bone ends are cleared of blood clot and soft tissue and are clamped in close and

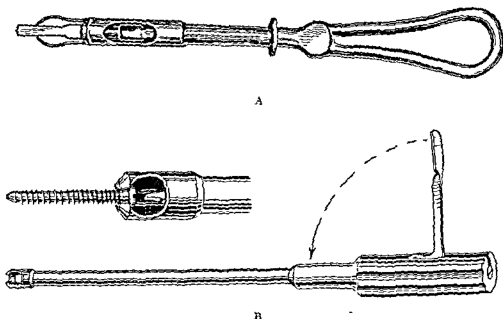


Fig. 103.—Screwdrivers incorporating holding devices.
A, Sherman's B, Williams's

accurate contact. After correct alignment has been confirmed, a hole is drilled obliquely across the plane of fracture with the $\frac{7}{64}$-in. or $\frac{1}{8}$-in. drill; the hole in the first fragment should strictly be enlarged with the $\frac{9}{64}$-in. drill. A screw is selected of such length that, when driven home, its point just projects through the further cortex—that is, a screw whose shank equals the drill hole in length. The screw is driven. If there is plenty of room for another drill hole and screw without fear of splitting, this also is inserted. The wound is closed without drainage. External protection should be used until there is evidence of bony union.

Operation for plating a fracture of the shaft of a long bone.
Special instruments.—In addition to the instruments required for exposing the shaft of the long bone to be operated upon, the following are required *Volkmann's spoons for clearing the bone ends; Lane's bone-holding forceps; plates of various sizes; wrenches for bending*

these; standard screws as described (pp. 269, 270) of various lengths; drills of suitable diameter, usually $\frac{7}{64}$ in. and $\frac{1}{8}$ in.; a drillstock to take the drills, preferably motor (with a hand drillstock in reserve); screwdriver (at least one screw-holding and one plain) appropriate to the screws; a bone clamp to hold the plate and fragments while the screws are being inserted; perhaps a device to measure the diameter of the bone in selecting screws.

Operation.—The ends of the fragments are exposed as described in the appropriate section, cleared of soft tissue and blood clot, and brought together A suitable plate is clamped to the fragments so that all are held firmly in accurate apposition without angular or rotatory deformity and without any gap between the fragments. Screw holes are drilled, usually at least three in each fragment and extending through both nearer and further cortex. The screws are inserted, the clamp is removed, and (if slotted or oval-eyed plates have been used) the fragments are impacted before the screws are tightened. The wound is closed without drainage. In the upper limb the dressings may incorporate a plaster slab; in the lower limb a Thomas's knee splint is applied with knee-flexion attachment.

After-treatment.—In the upper limb, the plaster slab and stitches are removed at 10 days, and free movements are carried out for about 4 to 6 weeks. Thereafter it is probably safer to resort to plaster of Paris till there is good evidence of full consolidation. The lower limb is exercised without bearing weight till union has begun, and then walking is allowed with protection.

Operation for screwing a wedge fracture of the back of the lower end of the tibia. Special instruments.—As for the last operation, plus a Steinmann's pin on a holder.

Position.—The patient is placed on his affected side with the hip *and knee* of the affected side flexed, the foot resting with its outer aspect on a thick sandbag.

Operation.—The back of the lower end of the tibia is exposed through a vertical incision between the medial margin of the tendo Achillis and the posterior tibial vessels and nerve, the flexor hallucis longus being identified on the back of the loose fragment. Any blood clot between this and its bed is cleared away, and the fragment is speared with the Steinmann pin. The subluxation of the ankle is reduced by displacing the foot forwards and dorsiflexing it fully. It must be held so, without the least relaxation, till the end of the operation. The detached fragment is manœuvred with the Steinmann's pin till it is accurately in closest possible contact with its bed and there is no gap above the reduced talus. It must be held so till the screw is in place. A $\frac{7}{64}$-in. drill is introduced through a thick part of the fragment forwards and slightly upwards into the main fragment. The channel in the fragment is enlarged to $\frac{1}{8}$ in. or $\frac{9}{64}$ in. and a long screw is introduced. In these manœuvres the chief dangers are splitting or

displacement of the fragment. The wound is closed, and plaster is applied from toes to thigh, with the foot fully dorsiflexed and the knee semiflexed.

After-treatment.—Knee exercises within the plaster and toe exercises are begun at once. After six weeks a below-knee walking plaster is substituted, and it is retained for a further six weeks at least.

Nailing a fracture of the neck of the femur with a tri-fin nail. *Indications.*—So-called abduction fractures of the femoral neck, in which the femoral head is impacted on the upper angle of the distal fragment, unite with quite perfunctory treatment or none at all and should not be operated upon. Fractures with little or no displacement may similarly unite, provided there is no element of adduction deformity (coxa vara) which nearly always increases and leads to non-union. The most frequent fracture is the so-called adduction one, in which the head lies opposite the lower angle of the distal fracture surface and is either disimpacted or becomes so. This fracture does not unite unless reduced and efficiently immobilized The most effective external splinting—the full hip spica—is very uncertain in producing union and is often fatal to an elderly patient. Consequently internal splinting is demanded. This must not be applied under vision, because this would require exposure of the joint, which is too big an operation for most of these patients and might endanger an already precarious blood supply to the proximal fragment.

Pre-operative management.—One of two policies may be followed; early or delayed operation.

Nailing is a life-saving operation, and most surgeons favour its performance as soon as any primary shock has been overcome, hoping that freer movement will prevent such things as hypostatic pneumonia and bedsores. In such circumstances rapid reduction is carried out at the time of operation.

A few surgeons consider that delay is beneficial, if well managed Traction is applied to the limb by strapping or by an upper tibial wire or pin; the patient is sat up in bed, and kept so by lifting the foot of the bed enough to counter the traction, usually not less than two to three feet. Breathing and, if possible, more general exercises are started, and the patient is got into the best possible medical condition before operation. In the meantime the traction weight and the lift of the foot of the bed are increased until radiographs, taken every day or two, show reduction or as near reduction as can be obtained, when a medial rotation bandage may be added By this method, reduction is gentle; granted good nursing, patients reach the theatre in better condition, and little or no time under the anæsthetic is taken up with manœuvres for reduction.

Anæsthesia.—Unless there are special reasons against it, general anæsthesia is best. Spinal anæsthesia is also satisfactory but involves more disturbance of the patient. Local anæsthesia is uncertain and is not recommended

Instruments.—In addition to the soft tissue foundation set, the following are required: rugine, small bone levers, osteotome, mallet; special instruments as follows: graduated guides (Fig. 104), ruler of same length as the guides, introducer (electric or hand) for the guides,

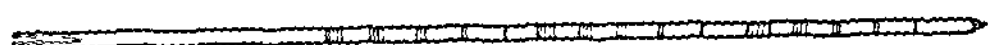


Fig. 104.—Graduated guide.

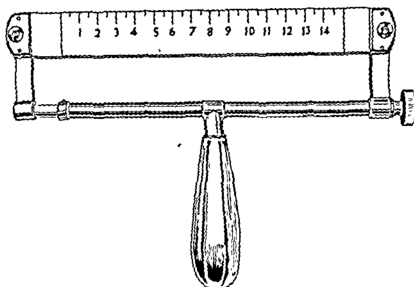


Fig. 105.—Expanding measuring scale.

preferably one of the many directors for the guides, preferably an expanding measuring scale (Fig. 105), canalized tri-fin nails with retaining pins (Fig. 106), perhaps a starter, a canalized punch (Fig. 107) and an impacter (Fig. 108). If skeletal traction has been applied, apparatus is required for removing this.

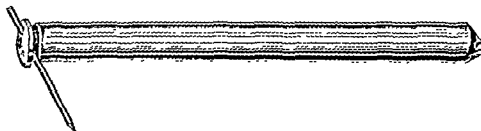


Fig. 106.—Canalized tri-fin nail.

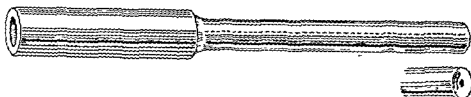


Fig. 107.—Canalized punch.

Facilities for rapid radiography are indispensable. This means dual X-ray sets, a shutter for sliding casettes beneath the patient, a convenient dark-room (or developing and fixing box) and a competent radiographer. With such, films can be adequately processed in less than a minute, but two minutes is a reasonable performance to expect and demand; this involves over-exposure and under-development with a special developer, used warm.

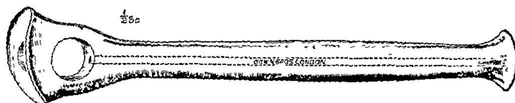


Fig. 108.—Impacter.

Method.—Although many techniques have been practised, the principles of the operation are the same in all that are effective, namely: (a) *reduction* of the fracture, (b) *exposure of the subtrochanteric region* and *introduction of a guide* across the fracture in good position under radiographic control, (c) *insertion of the nail* in the line of the guide, (d) *removal of the guide*, (e) *impaction*, (f) *fixation of the nail* against extrusion, (g) *closure*. Most variations in technique have been in the elaboration of various aids for accurate insertion of the guide. The introduction of a Smith-Petersen nail is beset with pitfalls, and no one should attempt it who has not made a study of these and thoroughly mastered a good technique by operations on the cadaver or under supervision.

Operation. (a) *Reduction of the fracture*.—In early operation the patient is placed on an orthopædic table with a transradiant pelvic rest, and the fracture is reduced, usually by Leadbetter's method of traction and medial rotation in flexion. When good reduction has been confirmed radiographically the feet are suitably tethered with the affected femur in medial rotation. In the delayed method, the patient is brought to the theatre with traction continued and still in bed if preferred. A padded casette changer is placed behind the buttock, so that antero-posterior views will include the hip and the trochanteric region. The foot of the affected side is rotated inwards and held so throughout the operation; a final radiographic check of reduction is made.

(b) *Exposure of the subtrochanteric region and introduction of the guide*.—The exposure resembles that described for the upper third of the femur. A small drill or gouge hole is made through the cortex of the outer aspect of the diaphysis about ¾ in. to 1 in. below the lower limit of the trochanter. From this point a graduated guide is inserted in the coronal plane of the body at about 50° upwards from the anatomical

horizontal. If it meets no increased resistance,* it is inserted for a distance of 9 cm. (or $3\frac{1}{2}$ in.). Its position is checked by antero-posterior and lateral radiographs of the femoral neck, and, while these are being developed, the exact depth of insertion of the guide is read off directly on a rule of equal length laid alongside its projecting part. If its position proves unsatisfactory, a second guide is inserted, and radiography will usually show this to be correct, in which event the first is removed. Radiographs give a magnified image; the factor of correction can be worked out by comparing the known distance of insertion of the guide with the length as it appears on the film. To avoid mental arithmetic and provide a scale for accurate measurement anywhere on the film, the scale (Fig. 105) is laid on the film and expanded until it gives the correct reading for the known length of guide. From the scale thus adjusted, measurements on the film are read directly in terms of centimetres or inches in the body. In this way the correct length of nail can be chosen, allowing about $\frac{1}{2}$ cm. for the shortening of the femoral neck that impaction will cause. Likely lengths are 8·5 cm. (about $3\frac{3}{8}$ in.), 8 cm. (about $3\frac{1}{8}$ in.), 7·5 cm. (about 3 in.) and sometimes 9 cm. (about $3\frac{1}{2}$ in.) or, in an exceptionally big man 9·5 cm. (about $3\frac{3}{4}$ in.). It is uncommon to need a larger size than 8·5 cm. for a woman.

(c) *Insertion of the nail.*—The nail is threaded over the guide and tapped in by mallet and punch, care being taken not to turn the edges of the nail on the cortex unless a "starter" is used first. After every few blows the punch is withdrawn, to ensure that the guide is not being driven ahead of the nail on account of a kink.

(d) *Removal of the guide.*—When the nail is almost home, the guide is removed. If this is done before the nail is well imbedded in the head, the latter may tilt when the nail is about to enter it. After further radiographs (unless time presses because of the patient's frailty), the nail is hammered fully home.

(e) *Impaction.*—The fracture is impacted by blows on a special punch or "impacter" held against the bone about the head of the nail.

(f) *Fixation of the nail against extrusion.*—A cross-pin is commonly used—Pidcock's pin—which demands that the nail should be suitably orientated when inserted and usually that a hole should be drilled in the cortex for the pin. This should be regarded as a temporary measure, as only bone over its head will lastingly retain a nail. A piece of cortex may be turned up over the head, but this poorly osteogenic material sometimes fails and it is better to bring down a sliver or cancellous bone from the great trochanter.

(g) *Closure.*—Closure without drainage, is carried out in three layers —vastus, fascia lata (femoris) and skin—and a very firm compression bandage is applied.

* This increased resistance [illegible]

After-treatment.—The limb is protected by a cradle and no external splinting is used. The shoe with cross-piece, often applied as a protection against lateral rotation, is a menace because likely to cause a serious twist if the patient turns in bed; it should be banned. If desired, lateral rotation can be controlled much more safely by a rotation bandage with light weight. General exercises continue after operation, and exercises are begun early for the hip and especially the knee. The patient sits in bed almost from the first and sits out as soon as adequate hip flexion is possible. Walking is possible within a few days but is usually delayed in the hope of diminishing the risk of osteo-arthritis. The real danger however is collapse of a necrotic head undergoing restoration, and, to be sure of preventing that, weight-bearing would have to be deferred for five years (*see* below).

The nail should not be removed except for complications. On occasion its removal many months after operation has revealed that union was not yet present.

Ischæmic necrosis of the femoral head as a complication.—With the advent of nailing, the most difficult problem has ceased to be preservation of the patient or the establishment of bony union, but has become that of ischæmic or avascular necrosis of the femoral head. After fracture of the neck, the head depends for its blood supply on capsular vessels passing along the surface of the femoral neck, especially the posterior part, where capsular fibres extend more proximally, and in some cases from the ligamentum teres, though to a much less extent. If the head loses its blood supply it dies. The framework of trabeculæ is preserved, and so the only radiological evidence of this event is a relative or real increase in density of the head, which may be revealed when rarefaction of the surrounding bone has become evident. A blood supply is essential for rarefaction, which depends upon the destruction of trabeculæ by cellular activity. A young vascular tissue later enters the head, *removing dead marrow* and trabeculæ in its path and replacing them by living fibrous marrow and osteoid tissue which becomes new bone—a process that Phemister has called "creeping substitution". Collapse occurs from yielding at the *advancing zone of substitution* It has happened as long as five years after the nailing operation.

It is unknown how often the vascular damage is done at the time of injury and how often during subsequent movement of the patient or reduction of the fracture, but certainly every care should be taken in these procedures. It may be that the delayed operation diminishes (though it does not abolish) the incidence of aseptic necrosis, just as gentle and gradual methods have seemed to improve the results in reduction of congenital dislocation of the hip and slipping of the upper femoral epiphysis, but this is pure conjecture

The smaller the proximal fragment, the more precarious is its blood supply, and, as might be expected, subcapital fractures are particularly

prone to lead to avascular necrosis; this is frequent too in young patients. It is tempting to anticipate it in such cases by primary excision of the femoral head and its replacement by an artificial substitute. This is a bigger operation than nailing and seldom gives lasting results, and so should be reserved for cases of established necrosis.

In an attempt to hasten revascularization and to provide extra scaffolding to a dead head, a bone graft has been inserted with the nail alongside it, but there is no real evidence that it does any good.

With collapse, the nail is either extruded, or, if fixed at its head, projects into the joint, and must be removed. If the patient is fit for such surgery, the necrotic head may be replaced by a prosthetic substitute (p. 111) with a brilliant immediate result. The more remote

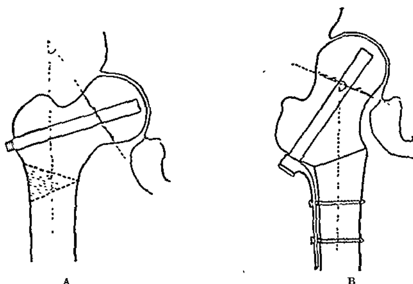


Fig. 109.—Wedge abduction osteotomy (A), controlled by nail-plate (B).
(After McNeur† From J. Bone Jt Surg.)

results have yet to be learned fully, but do not appear promising in active patients.

Vertical fracture of the femoral neck.—The more vertical a fracture in relation to the body, and therefore the less transverse to the femoral neck, the greater the shearing force and the more unsatisfactory the results of nailing, so that, with a "fracture-shaft" angle of less than about 30°, the results of ordinary nailing are bad (Eyre-Brook and Pridie*). In such cases it is probably advisable to tilt the fracture line into a more horizontal position by performing a wedge abduction osteotomy. Fig. 109 shows how a wedge abduction osteotomy, controlled by the plate of a nail-plate, may be used to nail an unusually vertical trans-cervical fracture (McNeur†).

* Eyre-Brook, A. L., and Pridie, K. H. (1941), "Intracapsular Fractures of the Neck of the Femur. Final Results of 75 Consecutive Cases Treated by the Closed Method of Pinning," *Brit. J. Surg.*, xxix, 115

† McNeur, J. C. (1953), "The Treatment of Subcapital Fractures of the Neck of the Femur with a Nail-Plate and Wedge Osteotomy," *J. Bone Jt Surg.*, xxxvB, 188

Nailing a per-trochanteric fracture.—In the past the problem with the *trans-cervical fracture* was its proneness to non-union and the lethal character of the only reasonably successful means of promoting union, namely, before the introduction of the nail, the plaster hip spica. Now the problem, at present unsolved, is avascular necrosis.

The per-trochanteric fracture, which is even commoner than the trans-cervical, presents none of these problems; non-union is rare, and the blood supply of the proximal fragment is ample. Granted reasonable nursing care, elderly patients do extremely well if they are sat up in bed with weight traction and a medial rotation bandage. (See an excellent paper by Murray and Frew.* The only thing that the author would quarrel with is that, to keep the patient sitting, the foot of the bed should not be on " low blocks " but should be elevated from two to three feet, a most important point commonly neglected.) Unless reduction is very good, slight coxa vara may occur; but this is not important, and, surprisingly enough, *it cannot be prevented by internal splinting,* which simply bends under the stress of weight-bearing. The advantages of internal splinting of per-trochanteric fractures are a more comfortable convalescence, earlier sitting out of bed (not earlier sitting), with earlier walking, greater ease in maintaining knee movement and an earlier return home. Against these advantages have to be weighed the dangers and disadvantages of a major operation, usually in an elderly patient, with the insertion of a foreign body, but in some clinics operation has proved less fatal than conservative treatment A good deal probably depends on the quality of nursing and the individuality of the surgeon.

Method.—It is technically more difficult to nail a per-trochanteric fracture than a trans-cervical fracture, because the distal fragment gives an inadequate purchase to the head end of the nail. The head of the nail is therefore replaced by or fits into a plate which can be attached to the femoral diaphysis with screws. The appliance, known as a nail-plate (Fig. 110), is obtainable with various lengths of nail and with various angles between nail and plate. Enough has been said of the techniques of nailing the femoral neck and the attachment of plates to make a separate detailed description unnecessary.

Intramedullary nailing of fractures.—The intramedullary insertion of Kirschner wires, Steinmann pins and rods of various sorts has been practised from time to time with the object of maintaining end-to-end apposition None of these internal splints bit the cortex, so that rotation has not been controlled, and they have been very little used. In 1940 Kuntscher† introduced nails of a cross-section which caused them to cut into the cortex, so that they were mechanically much better, although they also did not ensure complete immobility. Indeed it would be difficult to devise any intramedullary contrivance capable of immobilizing the fragments without fail, seeing that the

* Murray, R C, and Frew, J, F M. (1949), " Trochanteric Fractures of the Femur A Plea for Conservative Treatment," *J Bone Jt Surg*, xxxiB, 204

† Kuntscher, Gerhard, " Die Marknagelung von Knochenbruchen," *Arch f klin Chir*, 1940, cc, 443.

medulla is not of the same calibre throughout the length of a bone and that any simple appliance introduced into it must be of uniform calibre; the difficulty can be overcome to some extent by ensuring that the nail extends into cancellous bone at either end as well as traversing the medullary cavity. The method has been used on a large scale on the continent of Europe and is now being used extensively on the North American continent, but is less popular in the British Isles, where its use is very selective. Many limitations, difficulties and dangers have become manifest, and it is only now beginning to be possible to form a judgment.

Scope.—The principal advantage of the method in suitable cases is that it allows early movement. The disadvantages are that union may be delayed and that the insertion of a nail is a major operation, often of considerable difficulty and even danger. These are objections

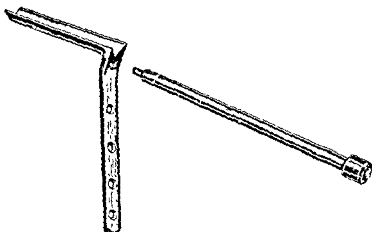


Fig. 110.—Nail-plate, for operative treatment of per-trochanteric fractures.

that can be made to any form of internal splinting, but the application of screws and plates gives firmer fixation with possibly less risk of infection and other dangers. Infection is particularly disastrous after nailing and has been frequent. Absorption of bone at the fracture site may perhaps be more harmful after plating than after nailing, which may allow telescoping.

The tendency, with experience of the method, is to limit it to very few bones, or even to fractures of the femur at its middle or at the junction of upper and middle thirds. It would seem that intramedullary nailing of a transverse fracture at such a site is justifiable in a patient well able to stand operation, if movement is of paramount importance and if delayed union matters little. The justification for nailing other broken bones is more doubtful, except the ulna in cases of Monteggia fracture-dislocation. Nailing has been used in fractures of long bones from carcinomatous metastases; every surgeon is familiar with such cases in patients who, except for the fracture, might have many months of comfort before them, and this application seems to be proving its worth. The method has been used for arthrodesis.

Finally, it has been suggested as a supplement to osteotomy or bone-grafting—in cases of mal-union or non-union of fractures, for instance, or in bone-shortening and bone-lengthening operations—a much more doubtful proposition. The method is unsuitable for fractures near joints and most comminuted fractures; it would hardly ever be justifiable in a child, and the author believes that it should not be carried out for open fractures.

Methods.—The nail (Fig. 111) may be introduced by the so-called "closed" method, or by the open method. Each is described here, as carried out for a fracture of the femoral shaft at, or above, its middle. The open method is the easier and the more popular.



Fig. 111.—Kuntscher nail.

The nail should be 4 cm. shorter than the normal femur, as measured from the greater trochanter to the knee. The girth of the nail should be checked by taking an antero-posterior radiograph of the femur with the nail of most likely thickness strapped to the thigh alongside it and then comparing the width of the magnified image of the nail with the width of the equally magnified image of the medullary cavity at its narrowest part.

In the closed method the fracture is accurately reduced under radiographic control on an apparatus that will maintain the position while the nail is being introduced. A small incision is made proximal to the greater trochanter, and the cortex is drilled where the trochanter joins the top of the neck. Through the drill-hole a guide is introduced, under radiographic control, along the proximal fragment across the fracture site and into the distal fragment. The selected nail is hammered in over the guide; the guide is removed, and the fracture impacted by manual pressure applied over the flexed knee.

In the open method the fracture site is exposed and the nail (or a preliminary guide) is introduced into the proximal fragment from below; the upper end is brought out through a second incision over the greater trochanter. The fracture is reduced under vision, and the nail is driven across the breach and into the distal fragment. This method is easier than the closed one, and is essential in fractures old enough for bone to have sealed the previously open ends of the medullary cavities of the fragments.

After-treatment.—Movements may be started from the first, but, as in the hip, there is considerable difference of practice between allowing early walking at about two to three weeks and deferring walking until union is complete and the callus consolidated.

Accidents and complications.—Apart from the dangers of sepsis and, in the closed method, of repeated radioscopy, the complications

may be divided into those happening during operation and those happening later.

Among complications occurring during operation is intramedullary jamming of the nail, so that it can neither be advanced nor withdrawn; this has happened often, and efforts to overcome it have caused surgical shock and splintering of bone. The surgeon who takes care to have a wide selection of nails and to test a sample radiologically for fit, who bears in mind that the medullary canal is often narrower in big men than in small women, who avoids sclerotic bone and especially long-standing cases with sealed ends to the fragments, and who assiduously avoids force—even he will be wise to include a hacksaw with his instruments so that a projecting immovable nail can be sawn short. An unduly tight nail may also cause separation and prevent impaction of the fragments. Another danger during nailing is penetration of the cortex. For instance, if a nail is introduced through the junction of trochanter and neck, instead of being passed from below, it may strike the medulla obliquely and penetrate the cortex of the proximal fragment; similarly, if the distal fragment is angulated on the proximal, so that the nail enters obliquely, it is likely to penetrate the cortex of the distal fragment, especially if this is porotic. In closed nailing, displacement of the fragments may cause the nail to miss the medulla of the distal fragment altogether. Nails that have penetrated the cortex, or missed the distal fragment have seriously damaged vessels, nerves and joints.

Later complications include not only breaking and bending of nails but also extrusion, which may take place with or against gravity.

BONE GRAFTING

General considerations.—Bone grafting exemplifies the importance of both a biological and a mechanical approach to surgical problems. It is ever necessary to remember that bone formation, bone survival, and bone destruction, depend upon the activities of cells and therefore upon an adequate blood supply. Bone formation depends upon the deposition of an intercellular substance by cells and its calcification through the agency of enzymes. Bone destruction can come about *in one way only*, namely the destruction of the intercellular substance by cells (osteoclasts) and the freeing of the imprisoned calcium. Calcium can be freed in no other way. Bone preservation is a combination of these processes, destruction and replacement taking place continuously just as in other tissues The periosteum forms cortical membrane bone from its deep surface and supplies the outer part of the bone with blood, and its superficial fibrous layer is a limiting structure.

Survival* of graft.—Most of the factors concerned in the survival of a graft may be considered in three stages: (*a*) immediate survival, (*b*) later survival, (*c*) ultimate survival.

* The word survival is here used to include replacement, which strictly is the *probable slow fate* of every part of the graft

Immediate survival.—After transplantation of autogenous bone, some osteoblasts on the surfaces of the trabeculæ survive, multiply and lay down new osteoid tissue and bone. The bone corpuscles in the substance of the trabeculæ die.

Later survival.—This depends on revascularization of the graft by inflowing young tissue, resembling granulation tissue, which removes dead marrow and trabeculæ and lays down new bone on the surfaces of dead trabeculæ so that there is a gradual replacement of dead bone by living. Thus the graft is replaced by advancing ingrowths from the periphery—so-called " creeping substitution " (Phemister).

Ultimate survival.—Ultimate survival depends upon function, namely exposure to stresses and strains. In general, compression, whether continuous or intermittent, tends to promote bone formation, and distraction does not.

Asepsis is another very important factor in bone survival, and, *although septic infection does not invariably spell the doom of a graft,* it puts it in great jeopardy.

Relative powers of survival of cancellous and cortical bone.—It is a matter of experience that cancellous bone survives more readily than cortical, at all events in the earlier stages. This is what would be expected from the enormous surface presented by its sponge-work of trabeculæ—and therefore the very large number of superficial osteoblasts able to survive—in distinction from the relatively small surface area of the compact bone which comprises the cortex. The same large surface area and big marrow spaces of cancellous bone favour its revascularization, whereas dense bone becomes revascularized with difficulty. When it comes to a question of ultimate survival, cortical grafts are often at an advantage, because they are easily given a mechanical function; it is more difficult to give a mechanical function to cancellous grafts except as " filling ". Because of their easy revascularization, cancellous grafts are better able to withstand sepsis than are cortical grafts. *If infected early, a cortical graft behaves like a foreign body;* if infected late, it may form a line of demarkation between living (revascularized) and dead parts, and the dead part may alone sequestrate.

Types of graft.—The special characteristics of cancellous and cortical bone have been described, but it remains to consider the forms in which each may be used for grafting.

Intramedullary grafts.—These, formerly popular for bridging gaps, are now so rarely used as not to require discussion.

Inlay grafts (Fig. 112A).—This method was formerly very popular, partly because very good stability could be achieved by good carpentry without the use of non-absorbable material such as screws Now that these are made of relatively inert material, inlay grafting is less popular, especially as it is difficult. In grafting for non-union, a channel cut across the fibrous and sclerotic areas is filled by a tightly fitting

cortical graft with the small amount of cancellous bone on its former medullary surface. The shape is either an elongated diamond, or else a portion may be cut with parallel sides by means of a twin saw. The graft should fit accurately and firmly. A useful variant of ordinary inlay grafting is the much simpler expedient of filling the gutter with tightly packed cancellous chips.

Onlay grafts (Fig. 112B).—Onlay grafts enjoy considerable popularity at present. The surface of the host bone is rawed slightly, and a strip of *cortical bone with a little cancellous bone on its deep surface is screwed* on to the prepared area. As in bone plating, care is taken that the

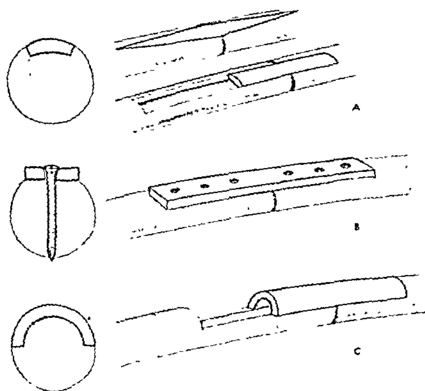


Fig. 112.—Common varieties of cortical graft.
A, Inlay. B, Onlay C, Half-thickness graft

screws are of suitable design, and that each takes a firm grip of the cortex in two places.

Half-thickness grafts (Fig. 112C).—In treating non-union of the shaft of a long bone, half the thickness of the bone may be removed as a graft, the ends of which may be reversed in such a way as to bridge the intersection

Chip grafts.—Originally used by Macewen, chip grafts are usually composed of cancellous fragments well packed together, and the advantages of this material have already been described. Chip grafts are used particularly to pack cavities and to fill or bridge gaps, in which capacity they are often used to supplement cortical grafts.

Only the leading methods of grafting have been described. The modifications and variations for special purposes are very great and some of these are illustrated elsewhere in this work.

Sources of grafts. Autogenous grafts.—In the selection of a source of bone in the patient himself, the following should be considered: (*a*) the type of bone required—whether mainly cancellous or mainly cortical, (*b*) the quantity needed, (*c*) the shape desired, (*d*) the injury involved in securing the graft, (*e*) the accessibility of the proposed source, in relation to the position the patient will occupy during the proposed operation, (*f*) the possibility of sacrificing the orthopædic patient's customary immunity from chest complications by separating respiratory muscles, as in taking iliac or costal grafts, (*g*) the innocuousness of the consequent scar. *Neighbouring bone* is a frequent source, and small grafts can often be removed from bone in the immediate neighbourhood of the operation without making any separate incision. *The tibia* is the ideal source for large cortical grafts, particularly because of its easy accessibility. *The ilium* is the best source of cancellous bone in the adult. The most economical way is to include the thin cortex with the graft. The iliac crest is exposed by an incision between the gluteal muscles and the abdominal muscles and freed of the latter by dissection; the upper parts of both the gluteal and the abdominal surfaces of the ilium are denuded subperiosteally. Horizontal slivers or vertical coronal wedges can then be removed with the osteotome. Alternatively, only the lateral surface may be denuded, and the cortical bone of the crest may be separated with the abdominal muscles. Pure cancellous bone can then be obtained from between the outer and inner tables of the crest, but this is more wasteful because some cancellous bone remains attached to the thin cortical plates. Finally the detached edges of the abdominal and gluteal muscles are sewn together and the wound is closed. *Fibular grafts*, when used, are obtained usually from the lower part of the fibula, but proximal to the lower tibio-fibular joint. The approach has been sufficiently described.

It is often possible to save time by using two teams—one at the donor site and the other at the site of implantation.

Homogenous grafts.—In bone grafting in children, especially in arthrodesis for scoliosis, it is difficult to get enough bone from the patient; so *stored bone* has come into use. Under rigid bacteriological control, bone removed at such operations as major amputations, and stored at a low temperature in "deep freeze" refrigerators, is used to supplement or even supplant autogenous bone. The stored bone behaves very like a fresh graft. The scarcity of suitable bone obtained at operation has led to the use of cadaveric bone. There are practical difficulties in removing this under aseptic conditions soon after death; and so now it is often removed at a convenient time, with only simple precautions, and boiled. It is then stored sterile in an ordinary refrigerator and given a final precautionary boiling just before use

(Lloyd-Roberts*). The dead bone should perhaps not be called a graft, but, like a graft, it is commonly replaced instead of being absorbed, provided it is given a task to fulfil.

Heterogenous grafts.—These have had little trial, but there is no certainty that a suitably-chosen boiled "graft" of animal bone would be less effective than a boiled homogenous "graft". It is true that the once popular "beefbone" pegs merely underwent exceedingly slow absorption when implanted, but their dense consistency made any other fate improbable.

Indications for bone grafting.—Before embarking on a bone graft operation, it is wise to consider whether this is the (*a*) safest and least damaging, (*b*) surest, and (*c*) simplest method of achieving the object Bone grafting is used in the following circumstances.

For un-united fracture with narrow intersection.—It is important to decide first whether the fracture is truly un-united; that is to say that cortical bone has closed the ends of the fragments making the original bone into virtually two separate bones. In such circumstances there is little chance that any treatment except grafting will succeed; drilling has often proved a waste of time. It is often, and indeed usually, recommended that the sclerotic bone at the ends of the fragments should be excised. This procedure adds to the duration and severity of the operation, and therefore to the likelihood of complications; it causes either shortening or else a gap which is unfavourable to bony union; additional stripping of periosteum interferes with the blood supply; if the fracture is near the end of the shaft it leaves one fragment undesirably short for holding the graft. For these reasons, the writer† would strongly deprecate rawing the bone ends, and would advocate the late R. C. Elmslie's method of cutting a channel *longitudinally* across the sclerotic area and inserting the graft tightly in this without other interference with the bone ends (Plate I). Phemister,‡ using onlay grafts, showed even more restraint, not even channelling the bone ends.

For bone deficiencies. *Fracture with a wide gap between the bone fragments*.—Such gaps were formerly bridged by intramedullary grafts, for instance from the fibula; but these were technically difficult to fix securely, interfered with endosteal new bone formation, and took a very long time to fill out and become strong enough to withstand stresses and strains. The usual procedure nowadays is to excise all scar tissue and make sure of a vascular bed, which is packed with cancellous chips; as it is difficult to subject these to longitudinal stress, a scaffolding also is supplied in the form of a massive onlay or inlay graft fixed by screws. A gap always makes bone grafting more uncertain.

Developmental gaps.—The classical example is the tibial gap in congenital pseudarthrosis, or in congenital bowing complicated by accidental fracture or misguided osteoclasis—an operation that should not be done for congenital bowing. In the past, grafting notoriously failed in these difficult cases, but later there were some successful results with substitution by the fibula, if present, and with bolted dual homogenous cortical grafts and intervening chips. The most successful results have come from McFarland's*† much simpler expedient of a posterior cortical " by-pass " graft, slotted into the back of each fragment and supplemented by cancellous chips. A few of these cases are complicated by so much shortening that early amputation promises a better functional and cosmetic result than any other procedure.

Osteomyelitis.—Gaps caused by osteomyelitis, usually in consequence of diaphysectomy, have become a diminishing problem with the introduction of penicillin. They present the same difficulties as a fracture with a gap, with much scarring and the possibility of a recurrence of old infection. Because of this risk, it may be wiser to carry out a cancellous graft only, without any cortical graft, and to operate in two stages, first excising the scar tissue as a test operation and only proceeding to the graft when healing has concluded the first stage satisfactorily.

Resection of tumour.—Gaps left after tumour resection may be filled with grafts. The problem is like that of a gap after fracture, except that there should be no important scarring, and also that very often one surface of a joint is necessarily sacrificed; consequently the graft may be made to bridge this and produce an arthrodesis, or alternatively a false joint may remain.

To fill cavities.—Bone grafts may be used to fill cavities left after curettage if this leaves too weak a structure. Examples are provided by some cases of solitary cyst, enchondroma, osteoclastoma and chronic bone abscess. *Cancellous bone is much the most suitable for the purpose, especially in the case of bone abscesses when sepsis is to be feared.*

To promote arthrodesis.—A bone graft may be used in two ways, (*a*) as a substitute for denuding the articular surfaces when this is considered undesirable, for instance in extra-articular arthrodesis of the hip in tuberculosis, or (*b*) as a supplement to intra-articular rawing, for instance in arthrodesis of the osteo-arthritic hip or ankle. If bone grafts are so used, care should be taken that they do not mechanically defeat their own object; for instance, in arthrodesis of the knee, two crossing oblique grafts may hold the denuded surfaces apart, an objection which does not apply to a single longitudinal graft; similarly, in arthrodesis of the shoulder by Brittain's method, it may be objected that the graft between the humeral shaft and the scapula forms the fulcrum of a lever of the first order such that the weight of the arm tends to separate the head of the humerus from the glenoid cavity.

* McFarland, Bryan (1940), "Birth Fracture of the Tibia," *Brit J Surg*, xxvi, 705
† McFarland, Bryan (1951), "Pseudarthrosis of the Tibia in Childhood," *J. Bone Jt Surg*, xxxiii, 36



A

Inlay graft applied



B

Bony union

PLATE I.—Inlay graft for non-union of 15 months old fracture, without resection of the ends of the fragments.

To arrest epiphyseal growth.—This is dealt with under the heading of limb equalization.

To hasten revascularization of dead bone.—This is mentioned under internal splinting in fractures of the femoral head.

As an accessory to other bone operations.—Other uses of bone grafting occur in arthrodesis (as described) and in holding open a gap produced by osteotomy (pp. 299–302).

Complications and sequelæ. Poor general condition.—However the patient's condition may appear, special attention should be given to the diet, especially the sufficiency of protein, minerals and vitamins, notably ascorbic acid and calciferol. The hæmoglobin should be estimated and a serological test for syphilis should be carried out.

Soft tissue anomalies. *Scarring.*—A grafting operation should not be performed through skin that is extensively scarred or adherent. The scar should be excised and replaced with good skin and superficial fascia by means of undercutting, counter incisions, a pedicle graft or sometimes a "cross-leg flap". The co-operation of a plastic surgeon is often desirable Deeper scar tissue must be excised in the course of the operation in order to provide a vascular bed for the graft.

Nerve injuries.—The repair of nerves must await bony repair, but need not necessarily await full bony consolidation.

Stiff joints.—Joints should usually be mobilized by active exercises before operation is possible. There are, however, cases in which the attempt would be a waste of time, for instance fibrous ankylosis of the elbow joint in association with un-united fracture of the humerus. In this case the fracture is dealt with first, and then an arthroplasty of the elbow is performed.

Sepsis.—*Sepsis before operation* must be cleared up in the usual ways by free drainage, the administration of antibiotics, etc., and the restoration of an unbroken covering of skin. Thereafter a pre-operative delay of three months or so may be desirable. Often the excision of scars will test whether sepsis has entirely subsided. Antibiotic "cover" is given before and after operation. In cases in which there has been sepsis, cortical bone and non-absorbable foreign bodies should be avoided if possible.

Sepsis after operation should be dealt with in the usual way. It does not necessarily mean sacrifice of the whole graft. In cases even of cortical grafting, sometimes part of the graft has survived and thrown off the dead part as a sequestrum after the formation of a line of demarcation.

Fracture of the graft.—The process of creeping substitution within a graft causes a zone of weakness at the advancing edge, and through this a breach may occur.

Fracture of donor bone at site of removal of graft.—Linear subperiosteal fracture of the tibia weakened by removal of a graft often

happens. The fracture unites readily. This unhappy episode in convalescence can be prevented by adequate protection. To avoid immobilizing both legs in grafting for un-united fractures of the tibia, the graft should be taken, if possible, from the same leg.

Instruments required for bone grafting.—*Foundation set; rugine,* various bone levers, mallet, osteotomes, gouges, file, large powerful bone-cutting forceps and gouge forceps, bone-holding forceps, bone punch; apparatus for insertion of screws and application of plates; motor saw set (unless only cancellous grafts are to be used); plaster outfit (or, in spine cases, a previously made plaster bed).

After-treatment.—Post-operative immobility of the part is important while vascularization and bony union are proceeding, and in some cases protection from the full strain of weight-bearing is needed for some time after bony union.

Bone transposition or bone substitution.—A wide gap in the radius, as in other bones, is filled by a graft with some difficulty and uncertainty, and with little hope of restoring useful pronation and supination. It is much simpler and more certain to implant the ulna into the lower radial fragment with good prospect of union at the total sacrifice of rotation.

Sometimes after osteomyelitis, the establishment of a gap in the tibia has been followed by fusion of the proximal fragment with the fibula, and weight has been borne through a hypertrophied fibula and the lateral malleolus. In such instances a similar operation is performed, the lower end of the fibular shaft being implanted into the lower tibial fragment. More often no natural fusion takes place between the tibial remnants and the fibula, and it is necessary to carry out an implantation at the upper end also, so that the fibular shaft is substituted for the missing length of the tibia.

OSTEOTOMY

Osteotomy means the cutting of bone, and usually, though not always, implies the surgical division of a long bone.

An osteotomy is named according to the site at which it is performed and the variety of operation. Certain examples are also eponymously described: for instance, subcutaneous supracondylar transverse osteotomy of the femur is known as " Macewen's osteotomy ".

Varieties of operation (Fig. 114).—**Transverse osteotomy** consists in cutting across a long bone in a single plane. This may be at right angles to the long axis, or alternatively the plane of section may be oblique, in which case the operation is known as an oblique transverse osteotomy. If the object is the correction of angular deformity only, the bone should not be cut through completely, the final division

being effected by fracture; interlocking of the consequent jagged extremities helps to prevent undesired rotation or lateral displacement.* If, on the other hand, these are desired, it is important to divide the bone completely by cutting.

Wedge osteotomy is the removal of a wedge of bone in order to correct angulation or compensate for a curve. As with transverse osteotomies, the general direction of the wedge may be either at right angles to the long axis of the bone or oblique.

Curved osteotomy resembles transverse osteotomy except that the incision through the bone is curved instead of plane, so that a convex raw surface is left in contact with a concave raw surface.

Longitudinal (or "linear") osteotomy is the production of a linear cut or cuts in the long axis of the bone. The term linear osteotomy is sometimes applied also to transverse osteotomy and should therefore be avoided as ambiguous.

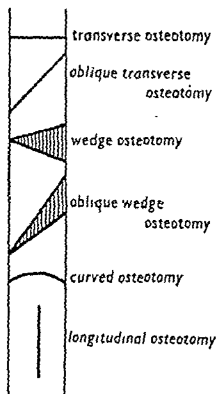


Fig. 114.—Varieties of osteotomy. (The shading represents bone to be removed.)

Instruments.—The following are required.

The soft tissue foundation set.

The additional instruments needed for the exposure of bones, namely a suitable tourniquet (if its use is possible), rugine, bone levers and perhaps deep retractors.

Bone cutting instruments: transverse and simple wedge osteotomies through cancellous bone are performed with osteotomes driven by a mallet. Very oblique transverse or wedge osteotomies, and longitudinal osteotomies, cannot be performed satisfactorily with osteotomes alone because of the tendency of the bone to split; consequently, unless the technique described below is used, a motor saw is essential for efficient work.

Curved osteotomy can be carried out along the direction of the proposed curve by means of a curved osteotome, or alternatively at right angles by means of a gouge or of a narrow osteotome with which it is possible to make a series of short straight cuts which together fashion a curve

Drills in very oblique transverse osteotomies, oblique wedge osteotomies and longitudinal osteotomies, the motor saw can be

* Strictly this is both osteotomy and osteoclasis The term osteotomy-osteoclasis has been used for a two-stage modification in which the osteoclasis is postponed for three or four weeks after partial wedge osteotomy with subperiosteal burying of the crumbled wedge—Moore, John Royal (1947), "Osteotomy-Osteoclasis A Method for Correcting Long Bone Deformities," *J Bone Jt Surg*, xxix, 119

dispensed with if the use of the osteotome is preceded by drilling in the line of section. This is tedious unless the drill is motor driven.

Sandbags are used, whenever possible, to receive, on the far side of the limb, the force of mallet blows applied to osteotome or gouge.

Osteotomy of the upper end of the femur. Indications.—The object of osteotomy at the upper end of the femur is deflection of the weight-bearing axis, which may be required in any of the following circumstances.

Deformity.—Deformity, from (*a*) ankylosis of the hip in bad position, (*b*) the various causes of coxa vara, including mal-union of fractures.

Instability of the hip.—Patients with old unreduced congenital dislocation of the hip, or those in whom the femoral head has been lost by disease (as in acute epiphysitis of infancy) or by design (as in operations for nearthrosis of the hip), are improved by an osteotomy which brings the weight-bearing axis of the femur nearer the mid-line of the body, increases the leverage of the abductor muscles and possibly provides a second bearing against the pelvis.

Osteoarthritis of the hip.—Osteotomy at the level of the lower lip of the acetabulum, with abduction of the femoral shaft and its displacement inwards, provides a new weight-bearing axis through the hip when the limb is once again brought into alignment after union. Surprisingly, it commonly relieves the pain of osteoarthritis of the hip*—for many years †‡ Relief sometimes follows the osteotomy even without successful inward displacement of the lower fragment, perhaps because unrestricted adduction of the upper fragment relaxes the capsule.§ The operation was formerly carried out in patients with intractable pain who were fit enough for the prolonged after-treatment in plaster of Paris but were unsuitable for an arthrodesis because of affection of the other hip or the spine, or because of frailty. It was used also in those with a range of movement worth preserving, but the operation always sacrificed part of this For a time osteotomy was largely [illegible] which usually leaves a more mobile hip an[illegible] demands no post-operative plaster and is [illegible]rail patients or troublesome for the knee. But an arthroplasty of the hip that gives consistently good and lasting results has yet to be devised. Arthroplasty is as fickle as osteotomy is dependable. The development of methods of internal fixation at the site of osteotomy|| relieves it of its greatest bugbear, post-operative plaster, but internal fixation presents technical problems, not the least being the great mechanical strain to be withstood if the hip is stiff.

* McMurray, [illegible] 716

[illegible]

Cervical fractures of the femur.—Un-united cervical fractures of the femur sometimes unite after osteotomy with displacement of the distal osteotomy fragment inwards beneath the old fracture line. High cervical fractures, and fractures in the young, so frequently fail to unite after nailing that primary osteotomy has often been advised for them. Though this operation promotes union, it cannot prevent necrosis of the head; consequently osteotomy has been largely supplanted by prosthetic replacement of the femoral head, the late results of which do not always reflect their early brilliance.

As an adjunct to other operations.—(*a*) In Batchelor's operation, to maintain stability after excision of the femoral head; (*b*) in the course of Brittain's ischio-femoral arthrodesis.

Sites and ordinary nomenclature.—The levels for osteotomy of the upper end of the femur (Fig. 115) are as follows: (1) Trans-cervical (obsolete, except in the treatment of slipped upper femoral epiphysis in some centres); (2) trans-trochanteric or per-trochanteric—through the greater trochanter; (3) inter-trochanteric—at a level between the greater and lesser trochanters; (4) sub-trochanteric—this term is sometimes applied to any site below the greater trochanter, but is more correctly confined to osteotomies below the level of the lesser trochanter. This operation is usually reserved for cases in which there would be a danger of lighting up old disease (for example tuberculosis) by an osteotomy at a higher level, and for stabilizing operations.

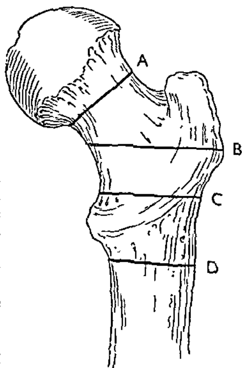


Fig. 115.—Sites for osteotomy of the upper end of the femur.

A, Trans-cervical (obsolete except in *adolescent* coxa vara and as part of other operations such as *excision* of the femoral head). B, Trans-trochanteric (through the great trochanter). C, Inter-trochanteric. D, Sub-trochanteric.

Operation.—The upper part of the femur is exposed, as described on p. 240. The bone is cut through completely and the lower fragment is manipulated into the required position (a broad gouge may be used as a skid if necessary, provided the sharpness is remembered). If the adductor muscles are unduly tight they should be divided subcutaneously (p. 185). The operation wound is closed in layers without drainage and shielded with a sterile towel. The patient is placed on a pelvic rest, an assistant carefully maintaining the best position of the limb under the operator's direction. A dressing is applied, the trunk and whole limb are swathed in cotton wool kept in place by a bandage which should grip firmly over the site of the wound.

A plaster of Paris case is applied so as to include the whole lower limb (except the toes) and with knee slightly bent; the plaster should either be carried to the opposite axilla or include the normal thigh. A window may be cut over the wound, and the edges of the plaster are trimmed so as to leave the epigastrium free and enough space in the perineal region to guard against soiling.

Comments.—In displacement osteotomy, as in osteoarthritis, the *plane of division should usually pass obliquely inwards and slightly* upwards to emerge just below the junction of the shaft and neck. The osteotome becomes readily deflected upwards on reaching the hard calcar, so fashioning an unwanted spur which may make displacement difficult or impossible.* This complication can be avoided by reflecting the soft tissues from the front of the bone, defining the angle between neck and shaft with a guide, and dividing the bone at the calcar cautiously from in front backwards before completing the osteotomy from the lateral aspect in the usual way. Alternatively, *especially if X-ray control is available*, a Steinmann pin may be introduced from the outer side in the proposed plane of section as a guide, along and below which the osteotome is passed.

At the end of the operation it is safe to carry out immediate correction and the application of plaster of Paris except in cases of extreme deformity, in which gradual correction is necessary. In cases of severe adduction deformity in adults, full correction (or over-correction to compensate for real shortening) may prove too much for spinal re-adaptation. In severe flexion deformity, the operation may be carried out to supplement a simultaneous Soutter's operation, and here the danger of immediate full correction may be particularly great.

Frequent mistakes are: unsuitable selection of cases, osteotomy at the wrong level, osteotomy at the wrong angle, failure to secure and maintain the best position; the plaster case may be of insufficient extent, too loose, inadequately moulded or unduly weak at important points, such as the gluteal region.

The use of internal fixation in suitable cases, instead of plaster, has been mentioned above. Special plates, blade-plates, nail-plates, and even nails, have been used.

After-treatment.—A radiological examination is made. In the absence of any special indication the wound is left undisturbed till about the tenth day, when the stitches may be removed through a window. If the plaster becomes unduly soiled, or there is doubt whether the limb is in the best position, the case may be renewed at the end of three weeks, preferably under anæsthesia, the stitches being removed if this has not already been done. One month from operation a shutter, cut from the back of the plaster opposite heel, calf and popliteal space, may be removed daily for knee and foot exercises. Two months after operation the case is removed, and, without

* *The same complication can spoil a Brittain's ischio femoral arthrodesis if the osteotomy is high, the spur preventing proper introduction of the graft*

anæsthesia, it is replaced by a well-fitting, moulded, short plaster of Paris spica which leaves the knee free and is applied next to the skin or almost so. The patient starts getting up and walking. Three to four months after operation the plaster case is removed, clinical and radiological examination is carried out, and, if union appears satisfactory, the spica is discarded; otherwise it is renewed.

Eponyms of osteotomies of the upper end of the femur.—This list is given for convenience of reference rather than for committal to memory.

Adams. — Subcutaneous transcervical transverse osteotomy (Fig. 115A).

Gant.—Subcutaneous subtrochanteric transverse osteotomy (Fig. 115D).

Schanz.—A special osteotomy for unreduced dislocation of the hip; transverse or wedge osteotomy at the level of the lower margin of the pelvis, with inward angulation at the site of osteotomy.

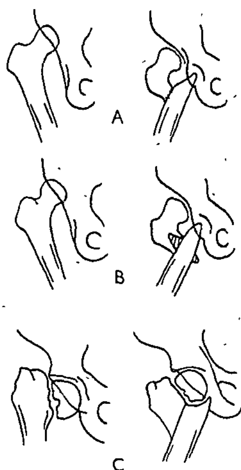


Fig. 116.—Varieties of Lorenz's bifurcation operation.

A and B, for dislocation C, for fibrous union of the fractured femoral neck (*A and C after Lorenz*)

Lorenz *—Bifurcation of the upper end of the femur by a very oblique transverse osteotomy, so that the shaft shall abut directly against, and receive weight from, the pelvis. No osteotomy without this express object should be called a Lorenz osteotomy. It was described in two separate groups of hip cases: (1) unreduced dislocation and (2) fibrous intersection of the femoral neck from un-united fracture or from infantile (cervical) coxa vara. In group (1) the upper limit of the osteotomy is opposite the top of the acetabulum, and the proximal end of the distal fragment comes to lie within it, separated by the capsule. The osteotomy may be carried out in an oblique transverse plane (Fig. 116A), or in a frontal plane so that the distal fragment lies in front of the proximal (Fig. 116B). In group (2) the upper limit of the osteotomy is opposite the lower margin of the acetabulum, under which the distal fragment is made to take a bearing (Fig. 116C).

* Lorenz, Adolf, "A New Method of Treatment of Irreducible, Acquired or Congenital Hip Dislocations," *New York med J*, 1923, cxvii, 130

McMurray.*—Lorenz's bifurcation osteotomy (the type used by Lorenz for fibrous intersections of the femoral neck) applied to osteoarthritis of the hip and often called displacement osteotomy.

Osteotomy of the lower end of the femur. Indications.—Genu valgum, or, more rarely, genu varum in the following circumstances: (1) the degree of deformity, the activities and the age of the patient warrant treatment but preclude the success of conservative treatment; and (2) no general condition (for example renal rickets) is present that would render operation dangerous or ineffective.

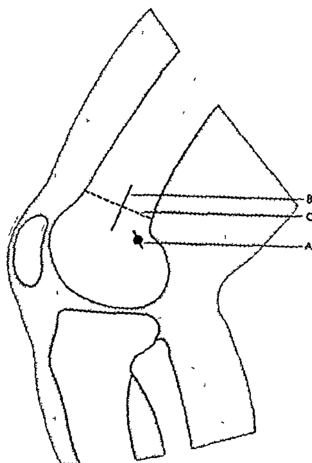


Fig. 117.—Macewen's supracondylar osteotomy of the femur.
A, Adductor tubercle B, Skin incision C, Bone incision

Varieties of operation.—The operation is performed by transverse osteotomy, either blindly (subcutaneously) through an incision on the inner side just large enough to admit the osteotome, or under vision through a longer incision on the outer side. The former is the classical operation of Macewen,† and, being the one most often done, will be described here.

Macewen's supracondylar osteotomy of the femur. Position. — The patient is placed on his back with the affected limb rotated outwards, the knee lying semiflexed on a sandbag, which preferably lies directly on the table without any form of mattress. The surgeon usually finds it most convenient to stand on the opposite side of the patient.

Operation.—A point is taken a finger's breadth above and a finger's breadth in front of the adductor tubercle (Fig. 117). Here a vertical incision, just long enough to admit the osteotome, is made down to the bone. The osteotome is passed along the blade of the scalpel which is then withdrawn. The osteotome is rotated about its axis through 90° so that the cutting edge lies at right angles to the shaft of the

femur, which is divided a little at a time. After every few strokes of the mallet the osteotome should be rocked in the plane of its blade to prevent its becoming jammed, but it should not be completely dislodged or its replacement may prove difficult. The postero-medial part of the bone is divided first, and section continued forwards and laterally from here until only the antero-lateral part of the bone remains intact. Finally this part is broken by an abduction movement with the knee extended. One or two skin stitches are inserted, the alignment of the limb is corrected and dressings are applied. The limb is enclosed in a lightly padded plaster of Paris case which includes the foot and should strictly include the hip also.

Comments.—(1) It is of the greatest importance, if this operation is carried out before growth is completed, that the line of section should be clear of the epiphyseal disc. Since this is at the level of the adductor tubercle the line of section described is safe provided the bone is divided in a plane parallel with the joint line. (2) Radiographs of cases after operation usually show an unnecessarily high division of the bone and often very imperfect alignment; this should be disregarded; it can be prevented by Moore's osteotomy-osteoclasis (footnote, p. 291). (3) No tourniquet is used, and it is customary to place a large swab round the osteotome at its point of entry through the skin, the ulnar border of the operator's hand and fifth finger resting upon the swab. (4) The final division is by fracture, and not by cutting, in order to diminish the risk of rotation deformity. The portion fractured should be antero-lateral, and not posterior, to avoid possible damage to the popliteal vessels by a bony spicule.

After-treatment.—Quadriceps contractions, practised before operation, are resumed forthwith. The plaster case is split at the end of about six weeks, the stitches are removed, and, if the bone appears firm, mobilization of the patella by a physiotherapist and active movements may begin, but weight bearing should be delayed for about twelve weeks from the time of operation, when radiographs may help in the assessment of union.

Osteotomy of the tibia. Indications.—Deformity that cannot be corrected by osteoclasis, usually from mal-union of fractures.

Site for osteotomy.—The best anatomical correction is given by osteotomy at the point of greatest deformity, but this is not always surgically desirable. The following should be *avoided* if possible: (1) the site of an old fracture, if there is sclerosis, because this makes division difficult and union uncertain; (2) the upper third of the bone, because of the danger of injury to vessels, especially the anterior tibial artery; (3) the lower third of the bone, because of the danger of non-union.

Varieties of operation.—Because most tibial osteotomies are through the shaft, union is often not very ready, especially in the lower third, and consequently transverse and wedge osteotomies are often

unsuitable because they leave only small areas of raw bone in contact. More often one of the following is indicated: (1) long oblique wedge osteotomy (Fig. 118A); (2) oblique transverse osteotomy (Fig. 118B).

Instruments.—For reasons already stated these oblique osteotomies require the use of a motor saw or of drills in addition to the other instruments, including osteotomes and mallet; screws, drills, drillstock and screwdrivers.

Position.—The patient is placed on his back with a sandbag under the affected leg.

Osteotomy by a long oblique wedge.—An Esmarch's bandage is applied to the thigh. A liberal straight incision is made over (or, better, adjacent to) the subcutaneous surface of the tibia in the region of the proposed osteotomy. The incision is carried to bone, and the periosteum is separated with a rugine. Bone levers are inserted on either side between the periosteum and the bone near the upper and lower ends of the wound. The shape of the wedge having been previously determined on tracings made from radiographs, it is removed with osteotomes after outlining with sawcuts or drill holes. The fibula is broken over a wedge (osteoclasis), or, if this is impossible, about an inch is resected. The raw surfaces of the tibial fragments are brought together, and the alignment is checked. Length may be maintained by a transfixion screw or two, but this precludes later adjustments of position. The wound is closed without drainage. Dressings are applied, and the limb is encased in a lightly padded plaster from the upper thigh to the toes The Esmarch's bandage is removed.

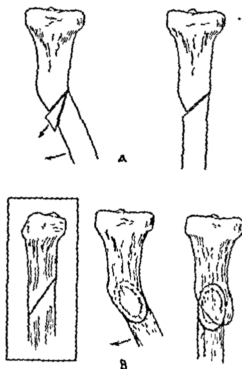


Fig. 118.—Varieties of osteotomy suitable for correction of angulation in the tibia
A, Oblique wedge osteotomy. B, Oblique transverse osteotomy

After-treatment.—The usual careful attention is given to the circulation of the encased limb Radiographs are taken to check the position Minor corrections can be made by wedging the plaster. Three weeks later, if this is loose or much soiled with blood, or any minor correction of alignment is required, the plaster is removed, the stitches are taken out, an unpadded plaster is applied and radiography is repeated Immobilization is usually needed for at least three

months, and, before the plaster is finally discarded, a clinical and radiological examination must be made without the plaster.

Oblique transverse osteotomy of the tibia.—The procedure is as for wedge osteotomy, except that no bone is removed and that the plane of section differs by 90° so that correction can be obtained by sliding the cut surfaces one on the other without separating them (Fig. 118B). This is an excellent osteotomy, as it is easy to divide the bone in precisely the right plane for correcting, say, a combination of anterior and lateral bowing, and the large areas of divided bone promote ready union. The plane of section can be calculated mathematically* from the angle of deformity as measured in strictly antero-posterior and lateral planes, but is more simply determined by finding the orientation of the bone which gives the best radiological appearance of correction and performing the osteotomy in the plane of the imaginary rays with the limb in this position.

Osteotomy of the humerus.—Osteotomy of the humerus is rarely required, but exceptionally a disturbance of growth at the lower end causes such a severe alteration in the carrying angle that correction is demanded. Bitter experience has shown that it is very difficult indeed to control the position of the fragments after an osteotomy at or near the lower end of the humerus, and the wisest course is to carry out a wedge osteotomy high enough to allow plating or an oblique osteotomy high enough to allow screwing, and then use one or other form of internal splinting.

Osteotomy for the deformity of disturbed epiphyseal growth at the lower end of the tibia.—Contrary to frequent supposition, traumatic separation of an epiphysis seldom interferes much, if at all, with growth; but a fracture through the epiphyseal plate often causes a bony bridge across this and premature fusion of the corresponding part, with consequent increasing deformity with growth. Before their devastation for munitions, England was richly endowed with railings, embellished with spiked tops. A child negotiating these would on occasion fall with his foot trapped between the spikes, sustaining a fracture through the lower epiphyseal plate of the tibia, a so-called railings fracture. This frequently led gradually to a varus deformity of the lower end of a somewhat shortened tibia beyond which the normally growing fibula made a bulky prominence. One way of treating this condition of traumatic talipes varus is to treat tibia and fibula as one bone and perform a wedge osteotomy based on the fibula. To this operation there are two objections. Firstly, the gross removal of bone further shortens an already somewhat shortened limb, and secondly, the resection does not include the lower epiphysis of the fibula, so that this can continue to grow and form an increasing

* If x be the required angle of deviation from an antero-posterior division, if y be the angulation of the bone measured in a strictly antero-posterior film, and if z be the angulation measured in a strictly lateral film, the value of x can be obtained from the formula $\log \tan x = \log \tan y - \log \tan z$.

prominence. An operation has been described* that overcomes these difficulties (Fig. 119). After preliminary planning on tracings from the radiographs, the lower epiphyseal plate of the fibula is excised, as suggested by Brockman,† with some adjacent bone. An osteotome is then driven almost across the tibia at the level of the former epiphyseal plate in a plane parallel with the lower articular surface (Fig. 119A). The cut is then prised open till the tilt of the articular surface has been fully corrected, and is held so by inserting into the gap the fragment removed from the fibula (Fig. 119B), supplemented, if necessary, by a small block of bone removed from slightly higher in the tibia. Thereafter the limb is treated in plaster of Paris until bony

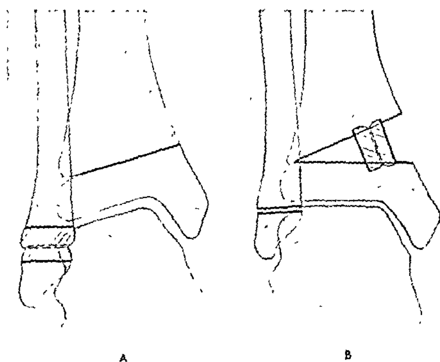


Fig. 119.—Osteotomies to correct traumatic talipes varus.

fusion has occurred. The patient is left with a correctly orientated lower tibial articular surface; the length of the limb is maintained; the fibula is of correct length relative to the tibia; the shape of the ankle is practically normal; and, finally, recurrence is impossible because the remnants of tibial epiphyseal plate are destroyed by the osteotomy and the fibular plate is removed.

Osteotomy for the correction of disturbed epiphyseal growth at the lower end of the radius.—A condition like the last can happen at the wrist from premature fusion of the lower radial epiphysis caused by injury to the growth plate, and can be corrected by an operation‡

" Proc Roy.
Med., 1932,
'onditions,"

on the principle of that for traumatic talipes varus. A portion of the ulna near its lower end is excised, including the epiphyseal disc but not the extreme end of the bone. A transverse osteotomy of the lower end of the radius is performed at the level of the previous epiphyseal disc in a plane parallel with that of the lower articular surface (Fig. 120A). The osteotomy is then prised open till the displacement of the lower articular surface has been wholly corrected, and the osteotomy is held open by insertion of the fragment from the ulna (Fig. 120B). The functional and cosmetic results have been good and the danger of further deformity is eliminated. A kindred operation is possible in Madelung's deformity.

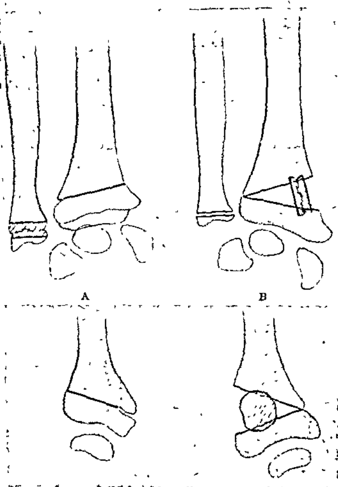


Fig. 120 —Osteotomies to correct deformity from premature fusion of lower radial epiphysis.

Osteotomy for malunited Colles' fracture.—The operation just described can be performed for a malunited Colles' fracture, but Campbell's operation,* though less anatomical, is usually preferable because it is simpler and does not involve trans-section of the ulna, which is only essential if an epiphyseal plate has to be removed. Osteotomy of the lower end of the radius is done in exactly the same way in Campbell's operation, but the fragment of bone used to keep it open is obtained by slicing off a piece of the prominent ulnar head vertically.

If only foreshortening of the radius, prominence of the ulnar head and lower radio-ulnar subluxation are troublesome—and not a gross tilt of the lower surface of the radius—it is probably better to be content with excision of the lower end of the ulna, which gives a surprisingly good functional and cosmetic result.

In the earlier stages before consolidation has occurred, open reconstruction of the fracture (p. 267) is possible and is preferable to osteotomy.

* Campbell, Willis C., "Malunited Colles' Fractures," *J. Amer. med. Ass.*, 1937, cix, 1105.

Before deciding to subject a patient, and very often an elderly patient, to operation for mal-union of a Colles' fracture, the surgeon should consider whether it will really be worth while, bearing in mind that, with the passage of time, mal-union becomes compatible with good painless function though the appearance remains bad.

OSTEOCLASIS

Osteoclasis means the deliberate fracture of a bone, and, on the rare occasions when it is carried out in this country, is usually performed manually with no apparatus except a padded wedge.

Indications.—The operation is almost confined to the tibia and fibula, being performed for rickety bowing and torsion, now rare, or for congenital torsion; this is shown by healthy children in varying degree, and the consequent in-toeing is gradually overcome by flattening of the feet, but rarely is extreme enough to justify osteoclasis. It is agreed that osteoclasis for rickety deformities should not be carried out till the disease is cured. Osteoclasis is preferable to osteotomy, not only because simpler and safer, but because some bending is achieved, whereas osteotomy converts one long curve into two shorter ones. Four important points should be borne in mind: (1) the normal tibia is bowed and twisted, and any exaggeration has a very strong tendency to disappear spontaneously unless active disease is present; consequently there should be great hesitation in advising osteoclasis; (2) this hesitation should be enhanced if there is no genu varum, because then straightening the legs will produce gross knock-knee; (3) osteoclasis should not be performed below about the middle of the tibia for fear of non-union; (4) *osteoclasis should never be performed for congenital bowing of the tibia*, because non-union is the inevitable consequence.

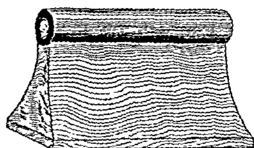


Fig. 121.—Osteoclasis wedge.

Osteoclasis of the fibula alone is sometimes required in osteotomy of the tibia in adults, to allow re-alignment (p. 298).

Manual osteoclasis of the tibia (and fibula).—The child should be deeply anæsthetized in order to avoid shock. A padded wedge (Fig. 121) is placed across the bare table and the child so manœuvred that the affected limb lies across the wedge with the site for osteoclasis opposite the apex of the wedge. The extremities of the tibia are gripped by the operator with his elbows straight, and in a sudden movement he transfers the weight of his body to his arms; usually the tibia and fibula break almost simultaneously but sometimes the fibula alone breaks and the tibia must be broken by a repetition of

the same movement. If, as is usually the case, both tibiæ require osteoclasis the opposite limb is similarly dealt with. The child is placed in the dorsal position and a padded plaster of Paris case is applied to each limb from the base of the toes to the upper thigh with the limb in the corrected position and the knees almost fully extended. Particular care should be taken to correct tibial torsion and not only bowing.

After-treatment.—The circulation in the toes is carefully watched. The limbs may be kept elevated for 24 hours, pain being relieved if necessary by drugs such as aspirin. The plaster is left in place for 6 weeks, after which ordinary activity is allowed.

Comment.—Osteoclasis is impossible if padding is left between the wedge and the table.

OPENING OF BONE

1. Curettage of Cavities

Indications. Solitary bone cyst.—Solitary bone cysts can sometimes be cured by curettage alone. If pathological fracture has occurred, the operation should be delayed until union has begun, in order to avoid collapse of the shell. Although fracture may lead to spontaneous cure, this may be less uncertain and more rapid after curettage, which also provides proof that the defect is not a solid lesion, such as an area of fibrous dysplasia or a chondrosarcoma. The lining of a solitary bone cyst is of variable amount and composition, so that a report on its histology should be interpreted with reserve. An otherwise typical solitary cyst lined with osteoclastomatous tissue is not an osteoclastoma. As curettage alone does not always lead to filling in of the defect, it may well be packed with stored or cadaveric bone.

Endosteal neoplasms.—Enchondromata of the digits are always innocent, and can be cured by curettage. It is important to avoid collapse of the shell, and the opening should be the smallest compatible with thorough curettage A pathological fracture should be allowed to unite before curettage is carried out. If these precautions are taken, bone grafting is rarely necessary. Curettage is still considered the treatment of choice for accessible osteoclastomata, though it is challenged by radiotherapy. Effective radiotherapy damages also soft tissues, the neighbouring joint and, in children, the growth plate. Radiotherapy has been unjustly condemned sometimes on account of the seeming radiological deterioration that may be the immediate response but which is purely temporary and commonly presages healing.

Chronic pyogenic bone abscess.—Curettage without drainage is sometimes followed by primary healing, especially now that penicillin is given. Sequestra should be carefully sought and removed. In cases of Brodie's metaphyseal abscess in children care must be taken not to damage the epiphyseal plate. Excision, in the rare instance in which it is possible, may be preferable to curettage.

Certain tuberculous foci.—In a case of a juxta-articular or juxta-epiphyseal tuberculous focus it may be possible to save the joint from infection by curettage of the tuberculous cavity. Furthermore, it may be that the opening of a relatively avascular tuberculous focus promotes access of blood-borne antibiotics, such as streptomycin.

Diagnostic curettage.—The foregoing can usually be diagnosed clinically, and pathological examination of the contents provides the proof; but curettage may be an essential step in arriving at a diagnosis in such conditions as eosinophilic granuloma.

Operation.—The position of the cavity is determined as accurately as possible by radiography. The site is explored with a narrow gouge until the cavity is found. If liquid issues, a specimen is taken. The aperture is enlarged sufficiently for every part of the cavity to be reached by a Volkmann's spoon, with which a thorough curettage is performed, the material removed being kept for pathological investigation. The wound is swabbed out with hot saline solution, and in septic cases penicillin and sulphonamide powder are insufflated. After the curettage of neoplasms some surgeons cauterize the cavity with liquid carbolic acid; this is of doubtful wisdom, and great care must be taken to leave no surplus in the cavity. If insufficient bony shell remains after operation the cavity should be packed with cancellous chip grafts. The wound is closed without drainage, and, after dressing, external splinting is applied if necessary.

2. Release of Pus

Indications arise for the release of pus in pyogenic infection of bone, as in the following conditions.

Acute osteomyelitis.—The most important role in the treatment of acute osteomyelitis is filled by penicillin. In penicillin treatment, pus calls for release. Some surgeons defer this till the acute stage is over; some seek to empty a subperiosteal abscess early; yet others explore the bone also, first the metaphysis and then the medulla. All report excellent results.

Chronic osteomyelitis.—In cases in which cavities or sequestra are suspected and there is a reasonable prospect of finding them with the assistance of radiography, exploration should be undertaken. Even without these criteria, persistent bone pain calls for exploration, which by itself may bring relief without revealing any focus.

Chronic bone abscess.—This has been discussed under the heading of curettage.

Operation in acute osteomyelitis. Special instruments.—In addition to the foundation set, which should include a probe, and the special instruments for exposure of bone, the following are required: gouges, osteotomes and mallet, drills and drillstock, insufflator for penicillin and sulphonamide powder, receptacles for pathological material; splints or the outfit for plaster of Paris.

Method of operating.—The approach to the bones has been indicated sufficiently. The presence of pus beneath the periosteum indicates deep infection nearly always, and may justify exploration of the bone. The metaphysis should be entered first, with a drill or a narrow gouge, because here pyogenic infection usually starts; care is taken not to injure the epiphyseal plate. The medullary cavity should probably not be opened at a primary operation unless pus is found in the metaphysis and can be traced to the medulla. If the medulla is to be opened, drills or gouges may be used. It is opened first at the metaphyseal end and is followed for such distance as the pus extends. Material should be taken for pathological investigation. The wound is closed without drainage and the limb is placed at rest in an elevated position. Chemotherapy and other general treatment is continued.

Operation for chronic osteomyelitis. Preparation for operation.—Attention should be given to the adequacy of the patient's protein and vitamin intake and the diet in general. The hæmoglobin should have been brought to a healthy level. If sinuses are present their bacteriology should be investigated and a scheme of treatment undertaken in consultation with a bacteriologist. If there are no sinuses, it may be possible to ascertain the characteristics of any organism found at a previous operation and to institute chemotherapy accordingly.

In war wounds and if tetanus has previously occurred a prophylactic dose of antitoxin is essential.

Method of operating.—In cases of extensive disease the operation may be severe, and a tourniquet is advisable, preferably a pneumatic one which can be released temporarily from time to time to oxygenate the nerves and to assist a distinction to be made between tissue which bleeds readily and that which does not. Scar tissue and sinuses, if any, are excised, cavities are opened, and sequestra are removed. The object of the operation is not only to release all pockets of pus and remove all dead tissue, but also to remove all tissue, whether soft or bony, having a poor blood supply. Every effort should be made to avoid pockets and to secure closure without drainage. Sometimes this involves the fashioning of flaps and sometimes the application of split skin grafts, which can be applied direct to raw bone or muscle but not to cartilage or tendon. Before closure the tourniquet is removed, bleeding is arrested (mainly by prolonged swab pressure), and appropriate chemotherapeutic agents may be insufflated. Alternatively, the tourniquet may sometimes be removed after closure and dressing. The limb is immobilized in an elevated position, and antibiotic therapy is continued.

3. Sequestrectomy

It is important to confirm that dead bone really is present, that it has separated, its exact site, and that it is single. Most of this information can be obtained in some cases by the palpation of a bare, rough, loose,

ringing, hard object with a probe introduced through a sinus, but this ... persisted in to the point of pain. ... emented by injection of sinuses ... views and especially tomograms. Concerning pre-operative, operative and post-operative procedures nothing need be added to what has been said about chronic osteomyelitis.

EXCISION AND RESECTION OF BONES

1. Excision of Whole Bones

Excision of a whole bone is not often required, and operations on the following only will be considered: (*a*) patella, (*b*) lunate (semilunar) bone, (*c*) scaphoid (carpal navicular) bone, (*d*) coccyx, (*e*) talus (astragalus).

Excision of the patella. Indications.—(1) Comminuted fractures of the patella in which the fragments present an irregular surface to the femur. (2) Severe cases of chondromalacia of the patella—fibrillation and erosion of the articular surface—and some severe cases of osteochondritis dissecans. (3) Some cases of patello-femoral osteo-arthritis in which the rest of the knee joint appears little affected. (4) Chronic osteitis of the patella, if more conservative measures fail; the knee joint becomes walled off in such a case and so is not endangered if due care is taken.

In operations for recurrent dislocation of the patella its articular surface should be inspected, and damage will often be found. The chondromalacia may be severe enough to call for excision of the bone. This should be regarded as no more than an incident in a more complete operation, such as a realignment of the quadriceps. Although good immediate results have been reported after patellectomy alone,* it cannot be relied upon to prevent recurrence of what is a dislocation, not of the patella alone, but of the extensor mechanism of the knee.† It would be surprising to find otherwise, because the patella, gliding in its groove between the condyles, must mechanically resist, rather than encourage, dislocation of the structure of which it is part.

Operation.—As it is very important to take up any slack in the quadriceps in suturing after the excision, it is possibly better not to restrain the muscle by applying a tourniquet. With the knee extended, a vertical incision through skin and superficial fascia is made over the mid-line of the patella from about an inch above its upper border to about an inch below the apex. The incision is deepened through the aponeurosis covering the patella, which is detached by dissection. The aponeurosis is sutured, care being taken to bunch it sufficiently to compensate for the laxity which otherwise remains after removal of the bone and is a source of quadriceps weakness The skin is closed

* McFarland, Bryan, "Excision of Patella for Recurrent Dislocation," *J. Bone Jt Surg*, 1948, xxxB, 158
† Burrows, H Jackson, "A Warning against Excision of the Patella for Recurrent Dislocation," *Brit med. J.*, 1938, i, 118

without drainage; and application of a compression bandage over copious cotton wool may be followed by a posterior plaster of Paris splint, care being taken to avoid hyperextension.

After-treatment.—Quadriceps contractions are started as soon as possible, but flexion exercises are postponed for about three weeks, when walking may begin. A moulded plaster of Paris posterior splint should be worn for walking until the knee can be flexed beyond a right angle.

Excision of the lunate (semilunar) bone. Indications.—The principal indications for removal of the lunate bone are (1) dislocation of more than about six weeks' standing, when manipulative reduction becomes impossible and operative reduction may cause or aggravate ischæmic necrosis of the bone and undue stiffness of the wrist; and (2) Kienböck's disease if the symptoms have failed to respond to immobilization.

Excision of the dislocated lunate bone.—Because the dislocation takes place forwards the bone is approached from the front through a midline vertical incision. It is usually easiest to displace the flexor tendons laterally and reach the bone from their medial side. Alternatively the median nerve may be identified and retracted with the flexor tendons inwards, the approach being on the outer side of these structures. The dislocated lunate bone is tethered at its anterior pole only, this coming to lie behind the rest of the bone when dislocation occurs The bone is freed by passing a cutting instrument behind it, care being taken not to injure the median nerve.

Excision of the lunate bone that has not been dislocated.—A three-inch incision is made on the radial side of, and parallel to, the extensor tendons of the index finger—extensor indicis (extensor indicis proprius) and extensor digitorum (extensor digitorum communis)—the middle of the incision should lie over the proximal row of carpal bones. The extensor retinaculum (posterior annular ligament) is divided and the tendons are drawn aside. The outline of the back of the lunate bone is carefully determined and the posterior ligaments are cut The joints are opened out by flexion of the wrist, and piecemeal division of the ligamentous attachments is proceeded with Detachment of the anterior pole is difficult and must be carried out carefully because of the nearby median nerve. The freed bone is removed from its bed and this is searched for residual fragments. The wound is closed without drainage. A short temporary plaster of Paris splint may be applied, the part is elevated, and finger movements are encouraged from the first.

Comment.—The operation is not easy, because of the close apposition of the carpal bones, in particular it may be quite difficult to find a cleft between the lunate and scaphoid (navicular) bones and between the lunate and triquetral (cuneiform) bones. It has been suggested that the operation should be carried out with the limb in a skeletal distraction apparatus. However, with care and patience, the bone can be excised whole without this assistance.

Excision of the carpal scaphoid (navicular) bone. Indication.—Almost the only indication is un-united fracture, and even this is doubtful. In established non-union of the scaphoid bone there is probably no operation—drilling, grafting, excision, or even arthrodesis of the wrist unless there is a severe arthritis—that, by and large, gives better results than conservative treatment, undramatic as they are. *This is a debatable statement, but the large fighting service experience has produced little evidence to refute it.* Whereas excision of the whole bone is of doubtful expediency, it is probably wise to excise early a dead proximal fragment comprising no more than a third of the bone.

Operation.—The bone is approached as for excision of the un-dislocated lunate bone, the back of the scaphoid bone is carefully defined and the posterior ligaments are cut. The wrist is flexed and the ligamentous attachments are divided, *with care not to injure the* radial artery. The bone removed, the wound is closed without drainage. A short plaster splint is applied temporarily, the hand is elevated, and finger movements are begun as soon as possible.

Comment.—Special care must be taken in defining the bone, because the wrong carpal bone has been removed! The counter (which the operator did not know) would be to remove the rest of the proximal row.

Excision of the coccyx. *Indication.—The operation is justifiable in* the few cases of chronic coccydynia with negligible neurosis. Sprain of the coccyx causes pain that often lasts weeks or months but gradually subsides in most patients of stable personality. In the neurotic, however, or in those with overwhelming personal problems, the pain may continue. In such patients coccydynia sometimes begins spontaneous without any injury and without any evidence of sacro-coccygeal arthritis. Some of them respond to explanation and persuasion, but, whatever the treatment, it should not be operative. On the other hand, in a very few patients chronic coccydynia is principally organic and is severe enough to warrant operation. In *such patients, the operation is justifiable and curative*, but they are few.

Special instruments.—Small bone levers and a small lion forceps.

Position.—The patient is placed prone with a sandbag in front of the pelvis. The surgeon stands on the patient's right, with assistant opposite.

Anatomy.—The coccyx usually comprises four segments, which typically are fused together. Separation of segments is sometimes found, the first in particular tending to be divided from the rest of the bone, so that it may be left accidentally *in situ* during operation, surgical division being carried out between the first and second coccygeal segments instead of between the fifth sacral and first coccygeal. This error may be avoided by remembering that the first coccygeal vertebra bears rudimentary transverse processes and also cornua which articulate with the cornua of the sacrum a few millimetres lateral to the main fibrocartilaginous joint. The fifth sacral nerve traverses the interval. The coccyx is so firmly embedded in

and incorporated with the pelvic floor that the soft tissue does not peel readily from the bone. The chief attachments to the superficial or posterior surface are the external sphincter at the apex, and, over most of the remaining area, the gluteus maximus blended with fibres of the sacro-tuberous (great sciatic) ligament. The coccygeus, attached to the lateral margins and to most of the anterior surface, blends with fibres of the sacro-spinous (small sciatic) ligament and anterior sacro-coccygeal ligament so as to separate this surface from the ano-coccygeal body which lies between the field of operation and the anal canal.

Pre-operative treatment.—The treatment before operation may resemble that for an anal or rectal operation.

Operation.—A vertical incision is made in the mid-line down to the fibres incorporated with the back of the coccyx. From now on the dissection is kept as close as possible to the bone. The tissues are dissected aside till the lateral margins and the apex are reached. The structures attached to these are divided, and the anterior surface is gradually freed from below upwards with curved scissors, the bone being elevated by means of bone levers or by grasping the apex in lion forceps The attachments of the cornua to the corresponding processes of the sacrum are divided, and the bone is finally freed by section of the fibro-cartilaginous disc joining it to the last sacral vertebra. Hæmorrhage, which is free, is arrested by securing and ligating or cauterizing the bleeding vessels, by hot saline solution and by pressure. The wound is closed without drainage.

After-treatment.—This may resemble that after an anal or rectal operation. It is important to adopt the lateral position when the bowels open, and, if the patient is, as usual, a woman, she must micturate prone. If these precautions are observed there is every expectation of primary union.

Excision of the talus (astragalus). Indications.—This operation was formerly carried out most often in the treatment of paralytic talipes calcaneo-cavus, but has now been replaced for this purpose by tarsal arthrodesis. It is still occasionally required for dislocation of the talus or for fracture-dislocation with necrosis of the posterior fragment. For the latter condition, calcaneo-tibial arthrodesis has been advocated, on the strength, we suspect, of comparison of bad excisions of the talus with good arthrodeses. If excision is to give a satisfactory result the principles laid down by Whitman must be followed, and it is important that surgeons dealing with injuries to the limbs should be conversant with them. They are explained in the next paragraph.

Method (Whitman's astragalectomy).—Simple excision of the talus is unsatisfactory because the space between the malleoli is too narrow to accommodate the calcaneum, whose upper surface is consequently prevented from coming into contact with the lower articular surface of the tibia. To overcome this difficulty a notch must be cut in each margin of the tarsus to accommodate the corresponding malleolus, which may itself be shaved down. In order to obtain a

well-balanced foot with good leverage for the tendo Achillis, the foot should be displaced backwards, and to allow for this the notches for the malleoli should be made well forward.

Special instruments.—Osteotomes, gouges and mallet, bone levers, lion forceps, Kocher's forceps, and plaster of Paris outfit.

Position.—The patient is placed on his sound side, the affected foot lying on its inner aspect; this and the knee are supported by sand-bags. The surgeon stands behind the heel with his assistant opposite

Operation (Whitman's astragalectomy).—A curved incision, convex downwards, is made on the outer side of the foot, from a point about an inch above the lateral malleolus and midway between it and the tendo Achillis, forwards below the tip of the malleolus and across the outer half of the dorsum of the tarsus to the outer and anterior part of the head of the talus. The peroneal sheath is opened, and the tendons and part of the lateral (external lateral, fibular collateral) ligament are divided. The foot is everted and the interosseous ligament severed. The talus is freed of its remaining attachments, beginning with its connections to the navicular (scaphoid) bone, and removed. The soft tissues are loosened from the lower end of the tibia and fibula sufficiently to allow backward displacement of the foot, and the malleoli are accommodated in notches cut in either side of the tarsus, the outer being at the level of the calcaneo-cuboid joint; shavings may also be removed from the malleoli themselves. A plaster of Paris case is applied with the foot in a position of moderate equinus and with the backward displacement carefully preserved.

After-treatment.—Plaster fixation is continued for not less than two months.

2. Diaphysectomy

Anything approaching excision of the whole diaphysis has hardly ever been practised except for osteomyelitis; the transformation wrought by penicillin in the treatment of acute osteomyelitis has made the operation almost obsolete.

The uncertainty of regeneration made the operation generally applicable only to bones which could readily be spared—a fibula, clavicle or rib.

Partial diaphysectomy is less uncommon, for instance: excision of part of a rib for drainage of an empyema or in the course of a thoracoplasty; excision of an inch or more of fibula in operations for tibial non-union; or excision of a length of fibula to provide a graft, though even this is uncommon with the diminished popularity of fibular grafts. A short length of the shaft of the ulna near its lower end has been excised to restore radio-ulnar movement lost through ankylosis of the lower radio-ulnar joint (Baldwin's operation).

Occasionally part of the shaft of a bone with its corresponding extremity has been successfully excised extraperiosteally for a locally malignant or potentially malignant growth not amenable to other

means less than amputation—an endosteal chondrosarcoma of the humerus or the femur for instance. The gap may be filled by a graft, as mentioned on p. 288, but it is [illegible] in a graft strong enough to meet the [illegible] -especially as it is often necessar[illegible] joint, so that the leverage to be withstoo[illegible] increased. Consequently, a trial has been made of killing the excised bone and contained neoplasm with heat and replacing it in the gap; external support is likely to be necessary during the very long time required for gradual replacement of the dead implant. Another substitute for the weak graft is the internal prosthesis, an artificial replacement made of an inert plastic or metal. Such devices, and especially the means of attaching them to bone, present many problems, and must still be considered experimental in spite of their immediate dramatic success.

In certain instances, when the whole skeleton of one lower limb has been so weakened by fibrous dysplasia as to make amputation at the hip seem inevitable, it has been possible to amputate through the thigh at a favourable site and replace the proximal part of the femur by an acrylic substitute (Seddon and Scales*). In this instance the problems of producing a fully weight-bearing joint and a satisfactory junction with bone do not arise.

EPIPHYSEODESIS

Epiphyseodesis is the operative production of bony fusion of an epiphysis with the diaphysis.

A simple example is the insertion of a bone graft across the epiphysis of the head of the femur to prevent further slipping in cases of epiphyseolysis In practice it is more convenient to use a Smith-Petersen nail in such a case. Another example is the excision of the epiphyseal plate, with the neighbouring epiphyseal and metaphyseal bone, as in the operations described on pp. 299–301 for the correction of certain deformities at the ankle and wrist in which it is desirable to arrest growth at the lower ends of fibula and ulna respectively. The most frequent use of epiphyseodesis at present is for limb equalization, as described in the next section. It has also been used at the upper end of the tibia and fibula to prevent "conical stump" after amputation below the knee in children, provided the stump is long enough already †

The usual method of growth arrest has been erasion of the epiphyseal plate with a chisel, drill or curette, and the application of a bone graft across the site of the plate at each of two diametrically opposed points.‡

Blount§ of Milwaukee has introduced staples to arrest growth temporarily. The plate itself is undisturbed but it is bridged at each

* Seddon H J, and Scales, John T, "A Polythene Substitute for the Upper Two-thirds of the Shaft of the Femur," *Lancet* 1949, ii, 795

† von Saal, Frederick, "Epiphysiodesis Combined with Amputation," *J. Bone Jt Surg*, 1939, xxi, 442

‡ Phemister, D B, "Operative Arrestment of Longitudinal Growth of Bones in the Treatment of Deformities," *J Bone Jt Surg*, 1933, xv, 1

§ Blount Walter P, "Control of Bone Growth by Epiphyseal Stapling. A Preliminary Report," *J Bone Jt Surg*, 1949, xxxiA, 464

of two diametrically opposite points by a group of three staples, each having one prong in the epiphysis and the other in the metaphysis. It is stated that growth is arrested temporarily and that it starts again if the staples are removed before puberty. If staples fulfil their early promise they will revolutionize epiphyseodesis on account of their simplicity and their revocability.

Staples will correct certain juvenile deformities by temporarily arresting growth at one part of an epiphyseal plate. Knock knee in a healthy adolescent is an obvious example. It is important to avoid any operation for deformities that commonly undergo spontaneous recovery—for instance, knock knee in young children.

LIMB EQUALIZATION

Inequality in length of the upper limbs of an extent that operation could remedy is of little practical importance, and the problem of limb equalization is really confined to the lower limbs. Before deciding upon operative equalization in length of the lower limbs, the surgeon should consider the following points. (1) The age of the patient and, in a child, whether the inequality will continue to increase. (2) Whether the inequality is of real importance, bearing in mind that small differences in length of the lower limb are common and often pass unnoticed, and that the inevitable postural scoliosis, which is present on standing but disappears on sitting, rarely becomes structural in uncomplicated cases. (3) Small amounts of shortening can be compensated in whole or in part by simple and inconspicuous alteration of the shoes, such as the use of a heel pad a quarter of an inch thick inside the shoe and the addition of a quarter of an inch to the heel of one shoe and the removal of a quarter of an inch from the heel of the other. (4) When apparent shortening is a factor, it can be overcome and apparent lengthening can be induced by osteotomy, provided that the patient has no changes in the spine which would make an alteration in the direction of the scoliosis undesirable. (5) Although [illegible] ble by operation, inequality of girth can [illegible] e muscle wasting or œdema may be as [illegible] in a woman as the necessity of a high shoe. (6) The functional improvement is often not very great because the disability of shortening is outweighed by the disability of muscle weakness, a stiff joint etc (7) If shortening is complicated by talipes equinus, it is disastrous to correct the shortening alone (8) The patient's attitude towards the shortening is very important, elderly patients usually have little objection, and prefer a high boot or shoe to a considerable operation.

Methods of equalization. *In both adults and children.*—Compensation may be achieved by lengthening the shorter limb, or shortening the longer.

In children only.—Equalization may be achieved also by accelerating growth of the shorter, or diminishing growth of the longer.

Lengthening the shorter limb.—Hypothetically this is the ideal operation, because it is usually the shorter limb that is at fault, and lengthening this restores proper symmetry, except that probably the lengthening will be confined to the segment above or below the knee and the original shortening may be distributed between the two. Leg lengthening is however a very difficult, time-consuming, often painful and even hazardous procedure, so that many surgeons have abandoned it. At most it should be reserved for special cases, for instance limb lengthening in a patient who is already short, so that shortening the longer limb is undesirable. Cases of infantile paralysis are easier to deal with than most, because of the laxity of the muscles, and because secondary operations to correct deformity will probably be required in any event. As the posterior calf muscles are much less extensible than the anterior ones, the tendo Achillis must be lengthened before the rest of the operation is undertaken, to diminish the tendency for the foot to be forced into equinus. Nevertheless deformity of the foot after lengthening the tibia is very common, and so any reconstruction of the foot should follow and not precede the lengthening operation. Formerly it was thought necessary to carry out rather complicated osteotomies and very thorough division of the fascial structures—periosteum, intermuscular septa, etc.—but now the tendency is the reverse: the operation is made as simple as possible, with the least interference with blood supply. The osteotomy is usually a long oblique osteotomy carried out with osteotomes after drilling without periosteal stripping. It is important to control the fragments by inserting two pins, or perhaps wires, in the proximal fragment and two in the distal. After operation the pairs of pins are distracted gradually by a screw apparatus at a rate of about one thirty-second of an inch daily, distraction being suspended if at any time there is evidence of vascular or neurological damage. Lengthening of two inches is a fair achievement, but lengthening up to four inches has been obtained in special instances. Tibial lengthening is more commonly undertaken and is more satisfactory than femoral lengthening, after which stiffening of the knee from binding down of the extensor apparatus may be a serious matter. The subject is dealt with more fully in an excellent paper by Allan,* who has had unusual experience and success.

Shortening the longer limb.—The two objections to this are, first that many patients resent interference with the sound limb, and secondly that the patient is made shorter, and not only shorter but disproportionately shorter, the trunk remaining of normal length. This is not noticeable except in unusually short patients.

Methods.—It is simpler to shorten the femur, as a single bone, than the leg with its two bones. Various levels have been advocated for femoral shortening. The writer prefers a site at about the junction of upper and middle thirds, as this interferes little with the quadriceps

* Allan, F. G., "Bone Lengthening," *J. Bone Jt Surg.*, 1948, xxxB, 190

mechanism and is reasonably removed from the entry of the nutrient artery or arteries in the middle third. The method of exposure has been sufficiently described. The simpler the osteotomy the better; after trying others, the writer has returned to the simplest of all, that of J. Warren White—transverse osteotomy (which need not be oblique, as described), suitable overlap, and transfixion of both fragments with long screws.* After closure and dressing, the limb is rested in a Thomas's splint with a knee-piece that allows movement from the first. Care must be taken not to damage the nutrient artery, *obliteration of which causes increased metaphyseal circulation* and growth in a child, in whom the very purpose of the operation would thus be partly defeated.

Acceleration of growth of the shorter limb.—In shortening from infantile paralysis, lumbar sympathectomy not only improves the circulation in the limb, at all events temporarily, but also accelerates its growth. Unfortunately the amount gained has proved too little and too uncertain to warrant operation.

The improved metaphyseal circulation and growth that follow obliteration of the nutrient artery or arteries has yet to be exploited for this purpose.

Diminution of growth of the longer limb.—This is achieved by epiphyseodesis at the lower end of the femur or the upper end of the tibia and fibula, or at both levels. This procedure is at present very popular in the United States of America, where the high incidence of infantile paralysis makes the short limb a more frequent problem The object is to carry out operation at such an age that, when growth ceases, the lower limbs shall be equal. There must always be an element of chance in estimating the correct age for arrest, such that (*a*) the expectation of growth in the good limb equals (*b*) the total expected deficiency in the affected limb. The expectation of growth in the good limb (*a*) is calculated on the assumption that lower femoral growth amounts to three-eighths of an inch yearly and upper tibial growth one-quarter of an inch yearly, and that girls cease growing a little before fourteen years of age and boys a little before fifteen. The total expected deficiency is guessed from the deficiency already present in relation to the time since onset. Age is expressed as " bone age ", ascertained by radiological examination of the patient's ossific centres. In all these factors there are obviously great individual variations which cannot be brought into any computation. Elaborate methods of accurate limb measurement by radiography are sometimes used, but these are not so much a practical as a research necessity. Methods of epiphyseodesis have been referred to in the previous section

* Knight, R A, "Anterior Poliomyelitis," *Campbell's Operative Orthopaedics*, second edition, edited by Speed J S., and Smith, Hugh, 1949, ii, 1456 St. Louis Mosby, London Henry Kimpton

CHAPTER VII

THORACIC SURGERY

By OSWALD S. TUBBS

Applied anatomy and physiology.—The elementary physiological principles governing respiration must never be forgotten by a surgeon who undertakes even the most trivial operation on the chest. The normal lung has a natural elasticity producing a constant propensity to shrink which is responsible for an average *negative* intrapleural pressure of about 10 cms. of water in inspiration and 5 cms. in expiration. Therefore, when the pleural space is exposed to the atmosphere, as must occur in any transpleural operation, the homolateral lung shrinks and becomes almost airless. Also, the mediastinum is drawn to the opposite side by the elasticity of the contralateral lung, as the mediastinum possesses considerable mobility, especially in children, unless it is fixed by disease. Further, the shift of the mediastinum is not constant, as each inspiratory effort of the patient increases the negative pressure on the contralateral side so that the mediastinum is drawn farther away from the opened pleural cavity, returning to its previous position on expiration. This mediastinal movement, often termed mediastinal flutter or flap, reduces the ventilation of the contralateral lung and, if continued, embarrasses the circulation. Therefore, when a transpleural operation is performed, it is preferable that the anæsthetist should improve ventilation and prevent mediastinal movement either by increasing the pressure of the anæsthetic gases on each inspiration (" assisted respiration ") or by abolishing normal respiration and subsequently ventilating the lungs entirely by alternating the pressure of the anæsthetic mixture (" controlled respiration ").

Finally, excluding those cases in which a whole lung has been removed, it is extremely important when the operation is completed that the lung, or, in cases of partial pulmonary resection the remaining portion of lung, should be made to fill as much of the pleural cavity as possible. This may be achieved either by raising the pressure of the anæsthetic gases before the chest is closed so that the lung tissue is inflated or by removing the air in the pleural space after the pleural wound is hermetically closed. In those cases where pleural drainage is provided, the drainage tube is connected to a water-seal drain and the anæsthetist should assist in re-expanding the lung tissue by raising the intrapulmonary pressure so that the air is forced out of the pleural space through the drainage tube.

A detailed knowledge of broncho-pulmonary anatomy is essential to any surgeon operating on the lung For this the reader is referred to reviews of the subject *

It is not sufficient to be familiar with the anatomy of the hilum of each lung and of each lobe, for it is often possible to remove the whole disease

* Brock R C 1946, "The Anatomy of the Bronchial Tree," Oxford University Press
Foster-Carter, A. F., "Broncho-pulmonary Anatomy" in Marshall, G, and Perry, K, 1952, "Diseases of the Chest," Butterworth

process by excising only part of a lobe and this requires a familiarity with the anatomy of the segments which compose the lobes These segments are more or less independent units each having its own bronchus and one or more branches of the pulmonary artery which are closely applied to the bronchus. The veins which drain the blood from a segment have an essentially different course from the arteries as they lie in the plane between two segments and receive tributaries from both of the adjacent segments. However, in addition to these intersegmental veins, some segments have one or more tributaries of the pulmonary vein confined to the venous drainage of that segment. During the surgical removal of a segment of the lung the vein which runs in the plane between two segments guides the surgeon in making his plane of cleavage. At the same time it must be obvious that it is necessary to divide numerous small tributaries draining from the segment undergoing removal into the intersegmental vein. A detailed account of the anatomy of the segments will be found in the references previously mentioned.

The surgeon must be prepared to meet with many variations from the standard anatomy; for example, the oblique interlobar fissures are frequently incomplete especially in their upper part close to the mediastinum and the transverse fissure on the right is often incomplete or absent.

Pneumonectomy for cancer of the lung should include excision of as many as possible of the lymphatic glands which drain the affected lung, the dissection being carried out so that the glands are removed *en bloc* together with the lung. Obviously this is only possible if the surgeon is familiar with the disposition of these glands.

SURGICAL TREATMENT OF DISEASES OF THE CHEST WALL

1. Inflammatory lesions.—Hæmatogenous pyogenic osteomyelitis of the ribs is very uncommon but operative treatment may be required, either to remove a chronically infected rib or to drain a complicating empyema. The technique is similar to that described for drainage of an empyema by rib resection (q.v.) but, when excising an osteomyelitic rib, it is important to remove the bone for the full extent of the infection.

Cartilage is notorious for its low resistance to infection and this is of particular importance in the chest as costal cartilage which is exposed to pyogenic infection is likely to undergo infective necrosis. It is therefore important to avoid cutting across cartilage when operating in an infected field. If proper drainage for an intrathoracic suppurative process necessitates section of a costal cartilage and if the cartilage is not in continuity with those of adjacent segments, the operation should be extended to include removal of the whole cartilage right up to the bone of the sternum. If the exposed cartilage is that associated with the sixth, seventh, eighth, ninth or tenth ribs the problem cannot be solved so readily as these cartilages are normally in partial continuity with one another. However, infection and subsequent necrosis may often be prevented by suturing some soft tissue, e g. muscle, over the exposed cartilage. If spreading chondritis of these cartilages does nevertheless occur it is then necessary to excise the whole group through a curved incision which starts over the lower end of the sternum and follows a course just above the costal margin. In those places where the cartilages are not isolated by a process of sequestration the surgeon may be tempted to remove the cartilages

together with the perichondrium, but it is preferable to leave as much perichondrium as possible in order to avoid a flail chest wall.

Actinomycosis of the chest wall is a diagnostic and not a technical problem as nearly all cases will clear up completely and permanently with adequate antibiotic therapy. Prior to the introduction of penicillin the best method of extirpating the disease was by wide resection but fortunately this is no longer necessary.

Tuberculous disease of the chest wall, that is disease which has no direct connection with an underlying empyema or pulmonary lesion, usually requires operative treatment for its cure. These cases usually present either as a cold abscess or as a recurring or chronic sinus subsequent to the external discharge of such an abscess. The lesions are most frequently seen in the parasternal region or over one of the lower intercostal spaces in the axillary line, and, with rare exceptions, are due to tuberculous lymphadenitis affecting the internal mammary group when the sinus or abscess is close to the sternum or the lateral intercostal glands when the lesion is in the axillary line. The infection often extends into adjacent costal cartilage or rib, and it is appropriate to mention here that tuberculous chondritis or costal periostitis is almost invariably due to extension from a neighbouring tuberculous focus and very rarely occurs primarily as a blood-borne infection.

The cold abscess or sinus secondary to lymphadenitis is exactly analogous to the "collar stud" lesions seen in the neck due to tuberculosis of the cervical glands. If the pathology is properly understood it immediately becomes clear that permanent cure requires careful removal of the superficial abscess cavity followed by resection of any cartilage or rib which has become secondarily involved and finally the complete excision of the underlying tuberculous lymphadenitis. In those cases in which the disease has produced [illegible]

of the underlying caseating gland.

If the wound is dusted with streptomycin powder and if the operation is combined with a three weeks' course of parenteral streptomycin (1 gm. daily combined with 15–20 gms. of *para*-aminosalicylic acid), which is started two days before operation, primary and permanent healing almost invariably occurs. The wound may be completely sutured if the escape of blood and serum during the first forty-eight hours is provided for through a separate stab drain.

Although the above discussion is confined to the common cause of tuberculosis of the chest wall, it is important to remember that a cold abscess or sinus overlying an intercostal space may very occasionally arise from disease of the spine but these cases should be recognized at once if proper clinical and radiological examination is made.

2. New growths.—A chest wall tumour is much more likely to be a secondary deposit in a rib than a primary lesion, so that, when considering surgical treatment, the first essential is to exclude as far as possible a primary lesion elsewhere in the body. This does not mean that excision of a secondary deposit may not be justifiable in exceptional circumstances for there are cases on record in which the removal of a solitary metastasis has been followed by freedom from further recurrence for many years, particularly where the primary lesion has been a hypernephroma.

It is also important to make sure that the growth in the chest wall is not an extension of a malignant growth of the lung. In cases of doubt it may be helpful to induce an artificial pneumothorax to see if the lung will fall away from the tumour. If the lung remains adherent to the tumour and there is still doubt as to the origin of the growth, the problem may be solved sometimes by examining the site of adherence through a thoracoscope (p 399).

Most of the primary chest wall tumours arise from a rib or costal cartilage but the recognition of the various pathological types—chondroma, osteochondroma, chondrosarcoma, giant cell tumour, "solitary" myeloma, osteogenic sarcoma and Ewing's tumour—is often difficult or impossible without histological examination. As might be expected the chondromata, which may become enormous and often recur unless very widely excised,

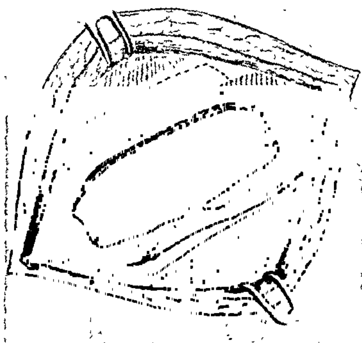


Fig. 122.—Method of repair of a small defect in the chest wall.

The periosteum has been elevated from the rib below and the dotted line indicates the site at which a similar flap will be raised from the rib above.

occur most frequently in the region of the costal cartilages. Because the histological nature of a tumour arising from the thoracic skeleton is likely to be in doubt, it is wise to plan to remove the affected rib or ribs together with the periosteum and underlying pleura As this involves opening the pleural cavity widely, the anæsthetic should be similar to that employed for any major thoracotomy (q.v.).

An incision is made through the skin, subcutaneous tissue and superficial muscles so as to expose both the tumour and the healthy chest surrounding it. If the tumour is confined to one rib, the latter is isolated from its periosteum (p. 334) for about ½ in. on either side of the tumour, leaving at least 1 in of apparently healthy rib between the site of periosteal elevation and the tumour. The two freed portions of rib are then divided with shears,

the section being made so that any bone freed of its periosteum will be removed with the tumour. The isolated portion of rib is grasped at one end in bone-holding forceps and slightly elevated. The pleural cavity is now entered beneath the proximal isolated portion of rib. The intercostal vessels are divided between ligatures. By further elevation of the affected portion of rib it is possible to observe the extent of the tumour on the inner side of the chest. If the tumour does not extend close to either the rib above or that below the one partially isolated, the removal of the tumour is completed by dividing the intercostal tissues and pleura close to the adjacent healthy ribs. If there are adhesions to the underlying lung but no evidence of neoplastic extension into it, the adhesions should be divided near to the lung.

If the defect in the chest wall is placed posteriorly it is not necessary to attempt to repair it, the operation being completed by suture of the overlying tissues after the anæsthetist has expelled the air from the pleural cavity by applying positive intrapulmonary pressure. Defects in the anterior or axillary part of the chest wall should be repaired wherever possible in order to prevent paradoxical movement in the post-operative period and to avoid the production of a permanently flaccid area in the chest wall which may permit the development of a lung hernia. If the defect is small, being the result of the removal of a single rib, it can sometimes be repaired by stripping the periosteum from the lower half of the rib above and the upper half of the rib below and suturing the tissue thus mobilized (Fig. 122). Larger defects due to removal of several ribs may be adequately sealed by suturing a flap of muscle, such as a portion of the pectoralis major, to the margins of the defect. An alternative and perhaps preferable method is to fill the gap with a suitably shaped piece of tantalum gauze which is anchored with sutures to the chest wall.

In the case of tumours on the inner aspect of the chest wall which have arisen from the soft tissues, for example fibromata and neurofibromata, the subperiosteal removal of a portion of the overlying rib (p. 334) will usually allow sufficient exposure to dissect the tumour from its surrounding structures.

TREATMENT OF PLEURAL DISORDERS

1 Recurrent and Chronic Spontaneous Pneumothorax

A spontaneous pneumothorax is due to the escape of air from the lung consequent to rupture of a lesion on its surface. In the past it was taken as a foregone conclusion that the pulmonary lesion was an active tuberculous focus but it is now generally accepted that many other conditions may cause a spontaneous pneumothorax, particularly emphysematous bullæ and lung cysts, either of which may be localized to a very small part of the lung.

The escape of air from the lung, whether the lesion be tuberculous or otherwise, may be valvular and cause a "tension" pneumothorax, that is to say the air continues to escape into the pleural cavity during inspiration but is unable to find its way back into the lung on expiration so that a strongly-positive intrapleural pressure develops. This causes complete collapse of the homolateral lung and gross displacement of the mediastinum to the opposite side and the patient therefore becomes extremely breathless. If the patient's condition is serious, the emergency may be overcome by inserting a needle through an intercostal space so that the entrapped air escapes externally and the positive pressure is thereby relieved.

Subsequent to the above or as a primary procedure in less urgent circumstances, a pneumothorax apparatus should be used to withdraw air from the pleural space until the pressures are slightly negative (a mean pressure of about 5 cms. of water). If the intrapleural tension recurs a short pneumothorax cannula should be inserted into the pleural cavity and fixed to the chest wall with strapping. This cannula is connected by rubber tubing with a water-seal drain (p. 332) so that the air may escape continuously from the pleural cavity through the water into the atmosphere. Exceptionally the air leak from the lung is so rapid that a cannula is of insufficient calibre to allow the air to escape from the pleural cavity fast enough and it is then necessary to introduce an intercostal tube (p. 332).

Spontaneous pneumothorax due to tuberculosis does not require further consideration here as the leak of air either ceases after appropriate emergency treatment (in which case treatment will be directed solely towards the causative lung lesion) or the pleural space becomes infected with tubercle bacilli converting the problem into that of a tuberculous pyopneumothorax (q.v.).

In cases of spontaneous pneumothorax *not* due to tuberculosis the air leak from the lung frequently ceases of its own accord and the air in the pleural space is gradually absorbed so that the lung re-expands and no further treatment is required.

However, in some patients the escape of air persists, thus causing a chronic pneumothorax, and in others, after the lung has fully re-expanded, the air leak recurs and this may happen several times with an intervening period of health lasting several months or years. In these cases of chronic or recurrent pneumothorax, thoracoscopy (p. 399) should be performed so that the surface of the lung may be inspected. If this examination shows gross but localized disease, e.g. polycystic disease, a condition which will have been suspected from proper radiological investigation, treatment must necessarily be by resection of the affected portion of lung (q.v.).

It is more common, however, to find a small group of little air vesicles, usually at the apex of the upper lobe, whose removal is completely unnecessary provided the leak of air can be stopped. Alternatively there is widespread emphysema which is obviously not amenable to resection surgery. In either case it may be possible to see the site of air leak and, if there are adhesions between this region and the chest wall, they should be divided with the cautery if this can be done with safety (p. 401), as the adhesions are sometimes responsible for perpetuating the escape of air from the lung. Persistence or recurrence of the leak should be prevented by instituting an artificial chemical pleuritis. The inflammation so caused helps to seal the hole in the lung and, if the lung is made to expand quickly so that the visceral pleura is brought into contact with the parietes while the inflammatory process is still in the acute phase, the pleural space will be obliterated by adhesions so that recurrence of the pneumothorax becomes an impossibility.

Some surgeons produce an artificial pleurisy at the time of thoracoscopy by introducing a second cannula through which a swab moistened in 10–15 per cent silver nitrate is passed on a holder and this is used to paint the area of the lung from which the air is thought to be escaping. Others pass the nozzle of a special insufflator through the second cannula and scatter iodized talc powder diffusely over the surface of the lung ("poudrage").

An alternative and equally effective method is to inject 10 minims of

10 per cent. silver nitrate into the pleural cavity through an intercostal needle using an all-glass syringe. This should be done after giving sufficient intravenous anæsthetic to make the patient unconscious as it is otherwise extremely painful. After the injection has been made, an artificial pneumothorax apparatus should be used to withdraw as much air as possible from the pleural space so that the visceral and parietal pleuræ may be brought into contact. During the first few days following this intervention the patient should lie on the affected side dividing his time equally between the prone, lateral and dorsal decubitus. If this is combined with elevation of the foot of the bed the chemical inflammation will extend throughout the pleural cavity.

The patient usually develops a fever of about 101° F. accompanied by a serous pleural effusion. Progress must be followed radiologically from day to day during the first two weeks so that any effusion or air seen in the pleural space may be aspirated forthwith, as the successful obliteration of the pleural space depends on bringing the two layers of pleura into contact while the inflammatory process is still in the acute phase. This causes the patient a considerable amount of pain which requires relief by suitable anodynes, including opiates.

Occasionally air continues to leak from the lung following the production of an artificial pleurisy, so that it is not possible to bring the two pleural surfaces into contact by aspiration. In these circumstances a small (size 20) Malecot catheter should be inserted into the pleural cavity through the second intercostal space posteriorly and mechanical suction applied to this (pp. 331–332). If the air leak is very gross a small electric suction pump may be unable to deal with the volume required, in which case a pump capable of removing large volumes of air, such as the Sprengel pump, must be employed. The catheter is removed as soon as the lung can be shown to remain expanded when the tube is clamped.

2. Hæmothorax

Blood may collect in the pleural space as a result of operative or accidental trauma to the lung or chest wall or due to the rupture of an adhesion between the lung and chest wall, the last being termed a "spontaneous hæmothorax". If there is no infection present and if there has not been gross contusion of the tissues the blood may remain free from clot but this must not be anticipated in every case.

If the blood is left untreated in the pleural cavity it may be completely absorbed: thus there may be no permanent scarring of the pleura (so-called "pleural thickening") and, in a few cases, the pleural space itself is left almost free of adhesions. On the other hand, in other untreated cases, the blood clots and deposits much fibrin which may undergo organization and even calcification; consequently the underlying lung becomes almost functionless due to contraction and immobility of the chest wall combined with partial collapse of the lung. The fate of an untreated hæmothorax may lie anywhere between the extremes outlined above but unfortunately it is impossible to predict the final result of an individual case. If a hæmothorax is left to absorb spontaneously, infection may supervene at any time and convert the hæmothorax into an empyema: this complication is not always of

serious consequence but it may be so, particularly when the blood effusion is large as it is then probable that infection will lead to a total empyema.

It is also important to realize that blood in the pleural cavity acts as a mild irritant and consequently the bulk of the effusion is likely to be increased by the exudation of serous fluid. Finally, a hæmothorax which arises as a complication of a therapeutic pneumothorax is almost certain to be followed by progressive obliteration of the pleural space if it is left untreated.

For these reasons blood in the pleural space, unless very small in amount, should be removed as soon as possible and by the simplest method practicable.

If the blood has not clotted it may be removed by aspiration through a needle. If clotting has occurred, the clot may be broken down by the intrapleural injection of enzymes (streptokinase and streptodornase) and the fluid aspirated subsequently.

If the clotted hæmothorax has been present for a time sufficiently long to allow some of the fibrin on the surface of the lung and chest wall to become organized, treatment by intrapleural enzymes followed by aspiration is not sufficient as the scar tissue remains and will restrict lung function. The time taken for organization to occur varies considerably but a clotted hæmothorax of more than a month's standing is almost certain to have produced a layer of scar tissue which will require operative removal (" decortication ") if pulmonary function is to be fully restored. The necessity for decortication does not rest entirely on the time that has lapsed since the onset of the hæmothorax but depends on the rapidity with which the lung can be made to re-expand following treatment by enzymes and aspiration. If full re-expansion cannot be obtained quickly, say in two weeks, then decortication is required.

(a) Treatment by aspiration.—This is done under local anæsthesia with the patient in a comfortable sitting position in bed. Usually the blood collects in the lower and posterior part of the chest and may be withdrawn most satisfactorily through a puncture made in the scapular line. For this the patient may either sit on the side of the bed or lean forwards on a " cardiac table " Occasionally the blood collects in greatest quantity in the lateral part of the chest in which case the patient should sit back supported by pillows or a bed rest and with the arm of the affected side kept in abduction by placing the hand behind the head.

An intercostal space overlying the lower part of the collection of blood should be selected as the site for puncture. It is unwise to attempt to insert the needle into the very lowest limit of the hæmothorax as any fibrin present tends to sediment to the bottom and may block the needle, so preventing withdrawal of the blood. Also, in attempting to find the extreme base of the collection of blood, it is easy to select an interspace below its inferior margin, particularly on the

right side where the liver dullness fuses with the dullness due to the effusion. If this happens the attempted aspiration will result in either a "dry puncture" or a syringeful of blood from the liver, and the patient not only fails to gain relief but may also suffer pain in the shoulder due to transfixion of the diaphragm.

Having selected the site for aspiration a small quantity of 1 per cent. procaine is injected through a fine hypodermic needle into the skin and subcutaneous tissues. The skin is then punctured with a size 11 scalpel blade so as to avoid the need for heavy pressure in order to penetrate the skin with a large-bore needle. A two-way adaptor, preferably one to which the needle and syringe may be locked, is connected at one end with a 20 ml. syringe filled with 1 per cent. procaine and at the other end with a large bore (about 16 B.W.G.) needle. A portion of rubber tubing is attached to the side aperture of the two-way adaptor so that, when the fluid is withdrawn from the chest, it may be discharged quietly into a receiver.

The needle is passed into the skin puncture and the local anæsthetic solution injected gradually as the needle is being advanced through the intercostal space into the pleural cavity. The procaine should be used freely so that the operation is entirely painless. Entry into the hæmothorax is usually recognized readily by the reduction in resistance to further advance of the needle, but, if this cannot be appreciated, a negative pressure may be induced in the syringe by attempting to withdraw the plunger; this will be rewarded by the aspiration of bloody fluid as soon as the needle penetrates the parietal pleura.

The first syringeful of fluid is likely to be contaminated with procaine solution and should be discarded into the receiver after changing the position of the tap on the adaptor. When the syringe has been filled with the effusion for the second time, the tap is again turned so that the needle has no communication either with the syringe or the side aperture in the adaptor; the syringe is then disconnected from the adaptor and its contents divided equally between three test tubes, one of which contains about 1 ml. of 3·8 per cent. citrate solution. The citrated and one of the other two specimens are sent for pathological examination, the third specimen being placed in a rack in the ward so that it may be compared later with any subsequently aspirated fluid. After reconnecting the syringe the aspiration is continued by appropriate positioning of the two-way tap.

As much fluid as possible is withdrawn *provided* the patient does not develop a feeling of tightness, feel faint and sweat, or become dyspnœic. Any of these symptoms should be an indication to cease the aspiration forthwith. In any case, it is usually unwise to remove more than a litre of fluid at a single session. At the end of the aspiration 100,000 units of penicillin in 10 ml. of solution are injected into the pleural space in order to prevent secondary infection.

Aspiration of a hæmothorax may be undertaken 24–48 hours after the onset of bleeding without any likelihood of restarting the hæmorrhage. It is unnecessary and harmful to replace the effusion wholly or

in part by air as this prevents the all-important re-expansion of the apex of the lung.

Aspiration is repeated as long as any effusion persists or recurs, the aim being to get the pleural space dry at the earliest possible moment and to keep it so. To achieve this object it may be necessary to intervene daily or even twice daily.

(b) Treatment of clotted hæmothorax with enzymes and aspiration.—If a bloody effusion cannot be removed by aspiration due to the *deposition of fibrin the clot may be broken up by the injection of* enzymes derived from the culture of streptococci: these enzymes are known as "streptokinase" and "streptodornase".

The *principle solid constituent of a clotted hæmothorax is fibrin* which is broken down by streptokinase whereas the viscosity of pus in an empyema is largely due to the presence of desoxyribose nucleo-protein which is acted upon by streptodornase.* However, as a practical measure of manufacture, the enzymes available are a mixture of *streptokinase and streptodornase with the former predominating.*

Between 50,000 and 400,000 Christensen units (average 200,000 units) of streptokinase dissolved in 20 ml. of normal saline are injected into the hæmothorax. To obtain the maximum effect the dose should be divided into about *three equal parts and each portion injected into a* different area of the hæmothorax. *Fibrinolysis ceases spontaneously* at the end of 24 hours, the maximum effect being obtained about 18 hours after the injection. The optimum *time for aspiration is* therefore between 18 and 24 hours after the injection, when as much fluid as possible should be withdrawn. *It is important to continue* aspirations daily until no more fluid is exuded as *any residual fluid* may contain irritants and pyrogens. *If the clot is not all broken* down by the first injection, the dose may be repeated on alternate days

The intrapleural *injection of these enzymes* usually causes a febrile reaction (*T 101°–103° F.*), a *feeling* of general malaise, *headache, and* sometimes gastrointestinal symptoms such as nausea and vomiting. Amidopyrine 0·1 gm. given 8-hourly *on the day preceding* and the *day of treatment may prevent the febrile reaction and lessen* the other symptoms.

(c) Treatment of clotted hæmothorax by thoracotomy and evacuation of clot.—If the clot in a hæmothorax of *short duration* cannot be completely broken down with enzymes (which is exceptional) a limited thoracotomy should be performed in a manner *similar to* that recom-mended for

The post-op

decortication. Simple evacuation of clot will not restore full lung function if there has been sufficient *time for* partial organization of the clot on the lung surface and chest wall; the operation is unlikely to be successful if carried out more than three weeks from the onset.

* Sherry, S., Tillett, W. S., and Read, C. T., *1950, J. Thorac. Surg.*, xx, 393.

(d) Decortication for chronic hæmothorax.—When a clotted hæmothorax has been present for more than three weeks the clot on the lung surface and chest wall becomes more or less organized into a layer of fibrous tissue. It is then necessary to open the thorax widely and remove this layer which encases the lung and prevents it re-expanding. It is important also to remove all the scar tissue which lines the chest wall and covers the diaphragm so that full respiratory movement may be restored. This operation may be extremely tedious and require great patience for it sometimes takes several hours to do the job properly.

The chest is opened under general anæsthesia in the manner described under major thoracotomy (p. 353). An intravenous infusion should be set up before starting the operation so that blood may be transfused whenever required as the blood loss consequent to the separation of the scar tissue is sometimes large.

The site of the opening in the thorax should be chosen so that the hæmothorax is entered a little below its centre; there is then likely to be reasonable access for decortication of the diaphragm.

After separating the periosteum from the inferior border of the chosen rib, the periosteum on its deep surface is incised so as to expose the parietal layer of scar tissue. The latter is stripped from the chest wall in the neighbourhood of the incision by blunt dissection with a long hæmostatic clamp or curved blunt-ended scissors. As soon as a plane of cleavage has been defined the separation can often be continued most readily with the finger. If the layer of fibrous tissue is thin and repeatedly fractures under the finger, it may prove easier to use a pledget of gauze held in a long hæmostatic clamp. In old-standing cases it may be necessary to use very heavy pressure to strip the scar tissue from the chest wall and, from time to time, sharp dissection with a knife or scissors may be required.

When the separation has extended for two or three inches on either side of the opening in the chest, the exposure should be improved by the use of a rib-spreader. The hæmothorax may then be opened, if this has not already occurred accidentally, and the clot and fluid exudate removed so that the extent of the cavity and its fibrous wall can be clearly seen.

The separation of the fibrous tissue from the underlying tissues is continued until all the scar has been completely removed. The diaphragmatic layer is often the most difficult to separate and the surgeon must be careful not to tear the diaphragm from its origin in those cases where there is dense scarring in the posterior costophrenic angle.

Usually the layer on the surface of the lung can be stripped off very easily without causing any damage but sometimes there are areas where the scar is bound firmly to the lung and it may be necessary to use a knife in order to continue the separation. Any particularly adherent patch should be isolated by freeing the scar all round it. If, after this, it is still impossible to separate the patch without causing

gross damage to the lung, the fibrous tissue should be cut from the margins of the adherent area which is then left *in situ*, but patches larger than 2 cms. in diameter will interfere considerably with re-expansion of the lung.

In very adherent cases there is bound to be a certain amount of damage to the surface of the lung and consequently blood oozes from the small pulmonary vessels and, if the anæsthetist applies positive pressure, air leaks from the alveoli. Fortunately such hæmorrhage

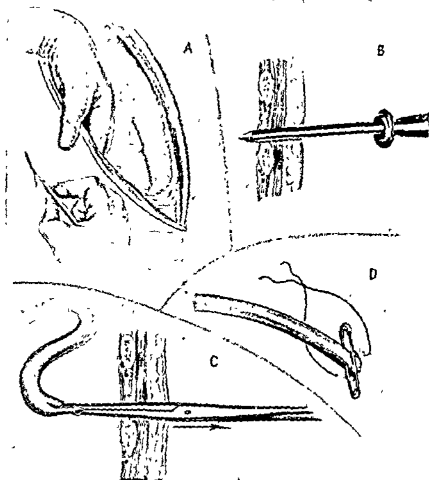


Fig. 123.—Method of insertion of basal intercostal tube following decortication (*see* text).

The same method is used for all operations involving major thoracotomy

stops spontaneously and the leak of air usually ceases within 48 hours of operation. When the decortication has been completed the interlobar fissures should be freed of adhesions as this facilitates re-expansion of the lung.

The anæsthetist is now requested to raise the pressure of the anæsthetic gases sufficiently to inflate the collapsed lung. When inflated the lung should reach the chest wall at all points; if there is evidence that it is still not completely free, further efforts should be made to liberate the restricted parts.

As soon as it has been shown that the lung is free to expand fully, the pressure in the anæsthetic circuit is reduced and the lung allowed to deflate. A trocar and cannula are then passed through the second intercostal space posteriorly and a size 24 Malecot catheter placed near the apex of the pleural cavity. The tube is held in this position by winding a piece of suture material round the tube at its point of emergence and fixing this suture firmly to the skin with adhesive strapping. This tube, colloquially known as the "apical sucker", is later to be used for the application of suction; it is therefore unwise to anchor it in position by transfixing it with a safety pin or even with a suture as the perforation is liable to cause the tube to leak.

Another tube is introduced near the base [illegible] This drain is a simple tube with [illegible] oduced by punc[illegible] Fig. 123A) and [illegible] the interspace (B): both trocar [illegible] drawn and a Mayo-Ochsner clamp passed into the ple[illegible] cavity along the track so made (C): one end of the tube is then grasped in these forceps and withdrawn through the chest wall leaving about 2 in. of the tube projecting into the pleural cavity. The tube is *not* withdrawn so that the end only just enters the pleural space as drainage may then become obstructed due to post-operative elevation of the diaphragm. As this tube is used only for drainage it may be anchored in position by transfixion with a safety pin which is then fixed to the chest wall by long strips of adhesive strapping (Fig. 123D).

Penicillin powder is scattered throughout the pleural space in order to reduce the risk of secondary infection. Finally the thoracotomy incision is closed (p. 355), the lung being kept inflated meanwhile by the anæsthetist. The tube at the apex is occluded with a spigot and the tube at the base is connected with a water-seal drain (Fig. 124).

As soon as the patient has been returned to the ward the apical tube is connected to a suction apparatus which permits a controlled negative pressure. The object of this "apical sucker" is to maintain expansion of the lung at the apex for this purpose a negative pressure of between 2 and 5 cm of mercury is usually adequate. If there is much leak of air from the aveoli the suction may cause this leak to persist; therefore, if air is constantly drawn through the tube it is wise to discontinue suction and connect the tube to a water-seal drain. Suction may be reapplied as soon as the air-leak has ceased.

All post-operative care is directed towards obtaining early and full re-expansion of the lung and preventing the accumulation of pleural exudate Progress can only be assessed from frequent X-ray films which should be taken on each of the first three days and as often as required subsequently

If the lung expands well, the basal drain may be removed after 48–72 hours and the apical sucker 24 hours later provided expansion has been maintained. Any subsequent exudation of fluid must be treated early by aspiration; if the formation of clot prevents aspiration,

gross damage to the lung, the fibrous tissue should be cut from the margins of the adherent area which is then left *in situ*, but patches larger than 2 cms. in diameter will interfere considerably with re-expansion of the lung.

In very adherent cases there is bound to be a certain amount of damage to the surface of the lung and consequently blood oozes from the small pulmonary vessels and, if the anæsthetist applies positive pressure, air leaks from the alveoli. Fortunately such hæmorrhage

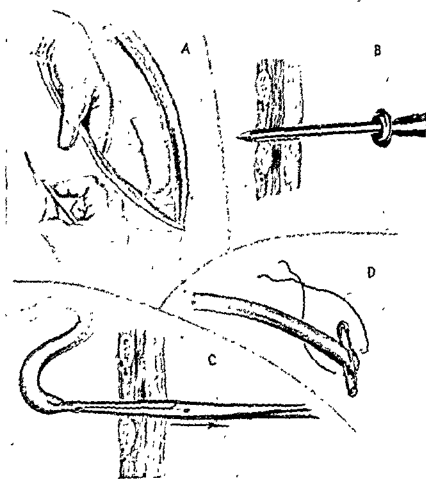


Fig. 123.—Method of insertion of basal intercostal tube following decortication (*see* text).

The same method is used for all operations involving major thoracotomy.

stops spontaneously and the leak of air usually ceases within 48 hours of operation. When the decortication has been completed the interlobar fissures should be freed of adhesions as this facilitates re-expansion of the lung.

The anæsthetist is now requested to raise the pressure of the anæsthetic gases sufficiently to inflate the collapsed lung. When inflated the lung should reach the chest wall at all points; if there is evidence that it is still not completely free, further efforts should be made to liberate the restricted parts

As soon as it has been shown that the lung is free to expand fully, the pressure in the anæsthetic circuit is reduced and the lung allowed to deflate. A trocar and cannula are then passed through the second intercostal space posteriorly and a size 24 Malecot catheter placed near the apex of the pleural cavity. The tube is held in this position by winding a piece of suture material round the tube at its point of emergence and fixing this suture firmly to the skin with adhesive strapping. This tube, colloquially known as the "apical sucker", is later to be used for the application of suction; it is therefore unwise to anchor it in position by transfixing it with a safety pin or even with a suture as the perforation is liable to cause the tube to leak.

Another tube is introduced near the base of the pleural cavity. This drain is a simple tube with a lumen of ¼ in. diameter. It is introduced by puncturing the skin overlying the chosen intercostal space (Fig. 123A) and inserting a trocar and cannula through the interspace (B): both trocar and cannula are withdrawn and a Mayo-Ochsner clamp passed into the pleural cavity along the track so made (C): one end of the tube is then grasped in these forceps and withdrawn through the chest wall leaving about 2 in. of the tube projecting into the pleural cavity. The tube is *not* withdrawn so that the end only just enters the pleural space as drainage may then become obstructed due to post-operative elevation of the diaphragm. As this tube is used only for drainage it may be anchored in position by transfixion with a safety pin which is then fixed to the chest wall by long strips of adhesive strapping (Fig. 123D).

Penicillin powder is scattered throughout the pleural space in order to reduce the risk of secondary infection. Finally the thoracotomy incision is closed (p. 355), the lung being kept inflated meanwhile by the anæsthetist. The tube at the apex is occluded with a spigot and the tube at the base is connected with a water-seal drain (Fig. 124).

As soon as the patient has been returned to the ward the apical tube is connected to a suction apparatus which permits a controlled negative pressure. The object of this "apical sucker" is to maintain expansion of the lung at the apex: for this purpose a negative pressure of between 2 and 5 cm. of mercury is usually adequate. If there is much leak of air from the aveoli the suction may cause this leak to persist; therefore, if air is constantly drawn through the tube it is wise to discontinue suction and connect the tube to a water-seal drain. Suction may be reapplied as soon as the air-leak has ceased.

All post-operative care is directed towards obtaining early and full re-expansion of the lung and preventing the accumulation of pleural exudate. Progress can only be assessed from frequent X-ray films which should be taken on each of the first three days and as often as required subsequently.

If the lung expands well, the basal drain may be removed after 48–72 hours and the apical sucker 24 hours later provided expansion has been maintained. Any subsequent exudation of fluid must be treated early by aspiration; if the formation of clot prevents aspiration,

streptokinase should be used to break up this clot as already described.

Decortication is designed to restore the respiratory function of the underlying lung but this object will only be achieved if breathing exercises are practised most assiduously under the supervision of a properly-trained physiotherapist. The patient should commence these exercises on the day following operation as it is much easier to restore mobility if an early start is made.

An infected hæmothorax does not require any special technique in its treatment. The infection can usually be controlled by the intrapleural injection of suitable antibiotics, combined with enzyme therapy if there is loculation due to clot. The sterilized cavity is subsequently treated on the same principles as an uninfected hæmothorax. If the infection cannot be eradicated, the case must be treated as an empyema (q v) although decortication is more likely to be successful than is the case with a "primary" empyema.

3. Acute Empyema

There is no doubt that the widespread use of chemotherapy in the treatment of pulmonary infections has been followed by a decreased incidence of acute empyema. Further, the antibiotic drugs, when properly used, make an empyema of less serious consequence to a patient but they also make it much more difficult to decide correctly on the best line of treatment as there are now so many alternatives.

In deciding how to treat a case, the following points must be considered:

i. The general condition of the patient.—In the past empyemas have been classified into two main groups:—(1) Metapneumonic, that is, the empyema does not develop or is not recognized until after the acute stage of the pneumonia is over. These cases are usually due to pneumonococcal infection and the patients are not acutely ill so that drainage by rib resection can be safely performed. (2) Synpneumonic, that is, the pleural effusion develops in the early phases of the pneumonia which is commonly a streptococcal bronchopneumonia. As the fluid often forms rapidly and in large quantities the patient may become desperately ill with severe dyspnœa, cyanosis and rapid pulse rate. In these circumstances the effusion has to be removed with the least possible disturbance to the patient, either by repeated aspiration or by the insertion of an intercostal tube but *not* by rib resection.

At the present time it is exceptional to see a case of pneumonia which cannot be brought quickly under control with suitable chemotherapy. Consequently it is uncommon for an effusion to develop while the patient continues to be seriously ill from the effects of the pneumonia. Thus the synpneumonic type of empyema has largely disappeared but the old classification still serves to remind the surgeon that rib resection drainage in an acutely ill patient must never be *performed*.

ii. The nature of the pleural exudate.—Diagnostic puncture should always be carried out before operation. This is performed in a manner exactly similar to that described for aspiration of a hæmothorax (q.v.). As in the case of a hæmothorax three test tubes, one of which contains a small quantity of 3·8 per cent. citrate solution, should be ready to receive samples of the aspirate. Two of the specimens, including the citrated one which is only used if the fluid is serous and likely to clot, are sent for pathological examination, and the third test tube is placed in a rack in the ward for comparison with specimens of fluid which may be withdrawn on later occasions.

An empyema is localized by the pleural adhesions round its margins and, when the pus is of creamy consistency, that is, when the cellular deposit exceeds the quantity of supernatant fluid after the test tube has been standing for 24 hours, these adhesions are sufficiently strong to prevent collapse of the whole lung when the empyema is drained. On the other hand, thin watery fluid such as that found in a synpneumonic empyema is a warning against exposing the pleural cavity to atmospheric pressure.

However, since chemotherapy is now almost invariably used to treat pneumonia, the macroscopic appearance of the pleural fluid is of less value in assessing the degree of localization of an empyema, for, in patients treated with antibiotics, the fluid may not thicken in spite of the empyema being well localized. In such cases it is important not to delay drainage if there are radiological or other signs indicating that the empyema is limited by adhesions.

A report on the bacteriology of the fluid should always be obtained before undertaking drainage as a tuberculous empyema may closely simulate one due to pyogenic organisms but requires totally different treatment. In patients who have been treated with systemic chemotherapy and particularly in those who have received intrapleural penicillin, the pus may be sterile but this finding alone does not lessen the necessity for drainage.

iii. The extent of the empyema.—(*a*) With large effusions and especially in those causing displacement of the mediastinum, sudden decompression, allowing escape of all the purulent exudate, may be dangerous because of the sudden change of pressure. In such cases, before undertaking drainage by rib resection, the size of the empyema should be reduced either by aspiration or by the insertion of an intercostal tube which is clamped so as to control the escape of pus. In addition, in empyemas due to penicillin-sensitive bacteria, reduction in the size of the cavity may be hastened by the intrapleural injection of 100,000 units of penicillin every two or three days. In acute fulminating pleural infections such as those which follow the intrapleural rupture of a lung abscess, such local chemotherapy is dramatically effective and may be life-saving.

(*b*) In bilateral localized empyemas both sides should not be operated upon on the same day. One side should be drained and the opposite

side treated by aspiration followed by a drainage operation in a few days' time.

iv. The nature of the causative lung lesion.—If an empyema is secondary to a bronchial carcinoma, tube drainage should be avoided if possible as the discharge adds to the misery of the patient. Careful investigation including bronchoscopy should therefore be undertaken if there is any reason to suspect the presence of a growth.

v. The age of the patient.—In infants, as the mediastinum is considerably more mobile than in adults, it is particularly important to be sure that the pneumonic process has completely cleared up and that the empyema is limited by firm adhesions before resecting a rib. Further, as children less than two years old have remarkable powers of absorbing an inflammatory exudate, complete resolution of an empyema is more often obtained by aspiration and local chemotherapy than is the case with older patients.

In debilitated senile patients, treatment by repeated aspiration combined with the intrapleural instillation of a suitable antibiotic is sometimes preferable to drainage by rib resection.

Drainage without rib resection.—An acute empyema may be drained without rib resection either by aspiration through a needle or by the insertion of an intercostal rubber tube through a cannula.

Drainage through an intercostal tube allows continuous drainage so that the pleural cavity is kept empty and the lung is enabled to expand so that there is no unnecessary diminution in its respiratory function. This advantage is more apparent than real as the patient usually gains more from sterilization of the pleural infection than from continuous drainage and truly-continuous drainage does not permit the sustained application of chemotherapeutic agents such as penicillin as both pus and drug drain out through the tube It is, however, possible to compromise by releasing a clamp on the tube every few hours so that the pus escapes, subsequently injecting the penicillin solution or other drug into the empyema through the tube which is then again occluded with the clamp. Another argument in favour of intercostal drainage is that very occasionally, especially in children, it proves sufficient, no subsequent rib resection being required. The disadvantages are that the patient may pull the tube out, the tube may become blocked with fibrin; a tube of sufficient size sometimes causes necrosis of the adjacent ribs and pain from pressure on the intercostal nerve; and, finally, the patient requires two operations instead of one, as drainage by rib resection is almost always necessary at a later date. These disadvantages can be minimized by careful supervision· proper external fixation will prevent the tube being pulled out· blocking of the tube by fibrin can often be overcome by irrigation with a little normal saline: rib necrosis and intercostal pain from pressure do not usually arise before it is time to resect a rib and the insertion of an intercostal tube is so simple that it is rarely considered " an operation " by the patient.

The advantages of aspiration are that it can be done with less disturbance of the patient, does not require any special instruments or post-operative nursing and leaves the patient free to move about in bed. Repeated puncturing every few days, which is necessary if aspiration is employed, is a disadvantage of the method but most patients prefer this to the limitation of movement in bed caused by an in-dwelling tube. If aspiration is combined with suitable local chemotherapy, infection of the chest wall at the site of puncturing is very rare and aspiration is not required on many occasions as either the fluid ceases to form, that is a true empyema is prevented, or the empyema soon becomes localized and therefore ready for drainage by rib resection.

In most cases, therefore, repeated aspiration, if combined with suitable chemotherapy, is to be preferred to drainage through an intercostal tube although the latter may be useful with very large effusions.

1. **Repeated aspiration.**—This is done under local anæsthesia in the same manner and with the same precautions as described for aspiration of a hæmothorax (p. 322). If the invading organism is sensitive to penicillin, 100,000 units of penicillin in 10 ml. of solution should be injected into the empyema before withdrawing the needle. The dose of penicillin may be varied according to the size of the empyema although the optimum dose for any given case remains a matter of opinion.

With penicillin-resistant but streptomycin-sensitive bacteria, about 2 gms. of streptomycin in 10 ml. of solution should be injected. Aspiration and intrapleural chemotherapy should be repeated every 2–4 days until the empyema is localized and ready for drainage by rib resection; this stage is usually reached after two or three aspirations. Occasionally paracentesis combined with intrapleural chemotherapy eradicates the inflammatory process and no further fluid is found after a few treatments so that operative drainage is not required. However, it is important to stress that aspiration should not be repeated again and again in an attempt to evade an operation, as patients so treated are very liable to finish up with much pleural fibrosis and they may be left with a chronic residual cavity or develop a broncho-pleural fistula.

2. **Drainage by intercostal tube.**—It is preferable to do this with the patient in bed and with the least disturbance possible, as it is an operation upon a very ill patient.

A trocar and cannula, such as are employed for thoracoscopy, are required. A Malecot's catheter, stretched on a metal introducer that will pass through the cannula, is chosen and its unstretched length measured so that it is possible to ascertain the length which projects inside the chest after insertion. The chest wall near the base of the empyema is infiltrated with local anæsthetic down to the pleura, and an incision half an inch long is made through the skin. The trocar and cannula are introduced with caution, so as to avoid trauma to the lung or diaphragm; they should be kept close to the rib below so

as to avoid injury to the intercostal vessels. The trocar is withdrawn and the catheter immediately passed into the pleural cavity through the cannula and the latter removed from the chest wall; the introducer is now withdrawn; the catheter is immediately clamped to prevent the escape of pus or the entrance of air; it is withdrawn until the surgeon

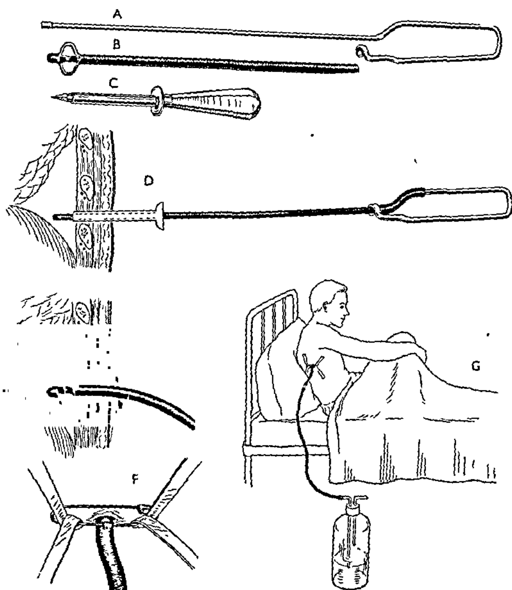


Fig. 124.—Introduction of a self-retaining catheter.

A, Metal introducer. B, Malecot's catheter. C, Trocar and cannula (made in three sizes). D, Stretched catheter passing through cannula into pleural cavity. E, Cannula and introducer removed, and catheter fixed to chest wall by means of safety-pin and strapping. F, Details of method of fixation. G, Catheter attached to water-seal bottle.

estimates that about one inch projects inside the pleural cavity; it is then fixed to the chest wall with a large safety-pin and adhesive strapping. The distal end of the catheter is joined by a glass connection to a rubber tube which is attached to a glass tube passing under water contained in a bottle under the patient's bed (Fig. 124).

Drainage with rib resection.—An empyema cavity is frequently lined by large masses of fibrin which, if a rib is resected, can be removed and prevented from organizing and forming a thick layer of fibrous tissue over the lung and chest wall. Streptococcal empyemas are classically supposed to be free from large fibrin deposits as the streptococci release enzymes which lead to fibrinolysis, but modern treatment with aspiration and local chemotherapy almost invariably kills the bacteria so that there is no further enzyme formation and consequently fibrin is deposited and does not undergo lysis.

All cases should therefore be drained by rib resection unless the exudate clears up before reaching the stage at which fibrin masses are deposited. It is possible that rib resection may be needed less frequently in the future as streptokinase can now be used to break up the fibrin and the fluid pus can subsequently be withdrawn by aspiration. This method of obviating the necessity for rib resection is still in the experimental stage and it is better that drainage of localized empyemas by rib resection should continue until there is further evidence of the value of these enzymes in the treatment of empyema. In spite of enthusiastic reports many of the results of such conservative treatment have been inferior to those obtainable by rib resection drainage due to the excessive amount of residual fibrosis.

Local anæsthesia is to be preferred to general anæsthesia as it causes less disturbance to the patient. The procaine solution (1 per cent.) is injected into the skin and muscles overlying the portion of rib to be resected and, after exposing the rib, the intercostal tissues above and below are diffusely infiltrated; this infiltration includes the intercostal nerves and thus provides regional anæsthesia for the costal resection which should be absolutely painless.

The correct place for the drainage opening is on a level with the bottom of the cavity, so that when the patient is sitting or standing no pus can collect. This site is determined by injecting 5 ml. of iodized oil into the empyema cavity on the day preceding operation and taking X-ray films in the antero-posterior and lateral positions. The oil drops to the bottom of the cavity so that it is possible to determine exactly the portion of rib which must be resected in order to give perfect dependent drainage. It must be remembered that a large basal empyema depresses the diaphragm and the latter rises after drainage so that the costophrenic sinus tends to be obliterated. Consequently some surgeons recommend that the ninth rib laterally, or the tenth rib posteriorly should be the lowest limits for resection, but it is better always to resect a rib at the very lowest limit of the cavity and subsequently to lengthen the tube when the diaphragm rises. Before starting the operation aspiration immediately above the portion of rib selected for resection should be performed in order to confirm that the site chosen does in fact overlie the empyema cavity.

The position of the patient for operation is that position which is most convenient for the surgeon; for example, if resection of a portion

of the ninth rib in the posterior axillary line is indicated, the patient lies on the good side with the upper scapula rotated forwards. If the patient is not fit to lie in the required position, he is not fit for drainage by rib resection; further treatment by aspiration should be carried out until there is sufficient improvement to justify rib resection.

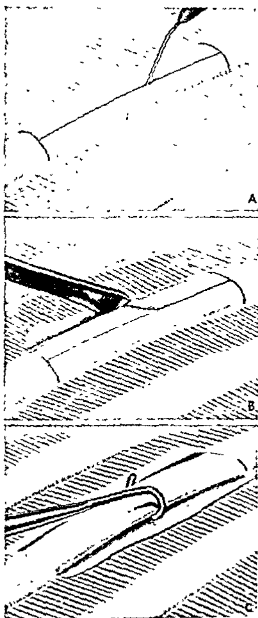


Fig. 125.—Diagram showing the method of stripping the periosteum before resecting a portion of rib.

A, Periosteal incision with the diathermy current. B and C, Stripping the periosteum.

If there is a broncho-pleural fistula present, the operation should be done with the patient in the sitting position so that he does not suffer the dangers and discomforts consequent to a large quantity of pus entering the lung through the fistula.

The incision is made over the rib and parallel with it, and in an adult should be from three to four inches long. If the site selected for operation is close to the sacrospinalis (erector spinæ) muscle a vertical incision provides better exposure.

Many surgeons prefer to use a vertical incision in all cases claiming that, if after resecting the chosen rib the drainage site proves too high or too low, the exposure provided by a vertical incision readily permits resection of the rib above or below. It is also claimed that a vertical incision is less liable to infection and allows the tube to lie more comfortably. On exposing the rib, the periosteum must be incised for two and a half or three inches; at either end of the incision a cut should be made at right angles, so as to avoid leaving a small piece of rib uncovered with periosteum, which increases the chance of necrosis of the rib ends. The periosteum and intercostal muscles are stripped from the rib with a rugine. Owing to the direction of the intercostal muscles it is important to work forwards on the upper margin of the rib when stripping the periosteum, and backwards along the lower margin (Fig. 125). Finally, with a child's size Doyen's raspatory the remaining portion of the periosteum is detached from the deep surface. The segment of rib which has been freed from its periosteum is divided

...oved,
right

level before incising the periosteum.

When this has been confirmed, the empyema is opened by incising the posterior periosteum and pleura. Initially this opening should be small in order to allow the pus to escape slowly, thus avoiding a very sudden change in pleural pressure which may cause discomfort to the patient and a desire to cough. Subsequently the incision is increased to the full length of the portion of rib excised, and the cavity is explored with the finger so as to determine whether the opening is low enough to secure dependent drainage.

In addition to fluid pus, the cavity often contains large masses of fibrin which should be removed with a pair of sponge-holding forceps and by gently rubbing the walls of the cavity with gauze. The removal of fibrin should never be so rough as to break down any of the adhesions round the margins of the cavity. For this part of the operation which may take fifteen minutes or more, the surgeon must be able to see clearly inside the empyema cavity: it is therefore essential to have either a special malleable light-carrier or some substitute such as the light on the end of a cystoscope: by introducing this inside the empyema cavity and by using the sucker to remove any residual fluid pus, the cavity can be properly cleared of all débris.

For drainage, a large rubber tube should be selected, with an external diameter of about $\frac{2}{3}$ in. and the end cut obliquely. It is introduced just inside the pleura so that it rests on the floor of the cavity with the oblique opening facing upwards. Some surgeons recommend division of the intercostal bundle between ligatures in order to reduce pain and lessen the risk of secondary hæmorrhage but it is doubtful if division of the bundle does in fact accomplish either of these objects The superficial muscles and skin are sutured round the tube so that there is no leak of air or pus alongside it. The tube is transfixed with a large safety-pin which is then anchored to the chest wall with long pieces of adhesive strapping; this strapping adheres much more firmly if the skin is previously painted with tinct. benzoini co.

On return to the ward, the drainage-tube is connected with a bottle under the bed by a glass connector and rubber tube of the same size as the drainage tube. This bottle has a wide neck and is one-third full of water it has a short exit tube for air and a long glass tube that goes down one inch under the water; to this latter the rubber drainage-tube is connected (Fig. 124).

Post-operative management. Local.—Except in the case of small empyema cavities (those of less than 200 ml. capacity) the drainage-tube should be kept connected with the bottle under the bed for the first week or two as the negative pressure thus induced assists in closure of the cavity. Drainage into the bottle also helps to keep the dressings clean Although it is desirable to free the patient as soon as possible from the restricted mobility consequent to water-seal

drainage, the latter may be needed for more than two weeks in the case of very large empyemas. As a general rule, water-seal drainage should be maintained for as long as the pressure remains highly negative and shows a big difference (more than 10 cms. of water) on deep inspiration and expiration.

Subsequently the tube is cut almost flush with the skin and the discharge from the empyema is collected in the dressings which are applied with gate-strapping, and *not* by an encircling bandage, so that there is no restriction of respiratory movement. It is unnecessary to remove the tube more than once every seven days, when the skin is cleansed with ether and a fresh tube and pin replaced and fixed. The adhesive strapping becomes soiled with the discharge, but so long as it retains its hold there is no need to replace it. If the skin is painted with tinct. benzoini co. before each application of strapping, it rarely becomes sore. Irrigations do not serve any purpose and should not be employed as they cause a great deal of extra work for the nursing staff and may be the means of introducing secondary infection.

Control of the drainage tube.—Great care and attention must be given to adjustment of the tube during convalescence as the constant provision of perfect drainage is far the most important factor in obtaining rapid re-expansion of the lung so as to obliterate the empyema cavity. During the period of water-seal drainage there should be a respiratory "swing" on the water level in the long glass tube. Cessation of this swing indicates an obstruction to the drainage and calls for immediate investigation as to the cause of the obstruction. In some cases the lumen has become blocked with fibrin and this can often be cleared by "milking" the tube, or if this fails, by injecting some saline along the tube. In others the tube has become too short to reach the cavity either because it has been pulled into the chest wall or because the diaphragm has risen sufficiently to excommunicate the end of the tube from the cavity. In these circumstances an increase in the length of the intrathoracic portion of the tube will restore the swing. In all cases antero-posterior and lateral X-ray films should be taken about two days after operation. If these films show a fluid level, the tube is almost certainly too long and requires shortening so as to provide dependent drainage

After discontinuing water-seal drainage, the length of the tube should be controlled by taking radiographs after the injection of 5 ml. of iodized oil into the empyema cavity. The oil is injected with the patient lying down on the good side and the tube is subsequently occluded with a spigot. Antero-posterior and lateral films are then taken with the patient standing or sitting-up. With this technique the position of the tube relative to the bottom of the cavity is clearly shown and the length of the tube is subsequently adjusted so as to provide dependent drainage. It is also often possible to see in these films the size of the empyema, particularly as a thin film of oil sometimes adheres to the boundaries of the cavity, and progress can thus be assessed.

Such radiographs, often referred to as "sinograms" or "pleurograms", should be repeated at least once a fortnight until it is shown that there is no longer any cavity present. The tube may then be removed. It is absolutely essential to maintain tube drainage as long as there is a cavity present, however small it may be and even if there is almost no discharge.

Breathing exercises greatly aid expansion of the lung. The classical exercises based on enforced expiration such as that generated by blowing up an air ring or blowing fluid from one bottle to another should never be employed as they have been completely superseded by active inspiratory exercises. The patient is taught to control both diaphragmatic and costal movement on each side, so that ultimately perfect function is restored. Active exercises of the shoulder girdle and vertebral column are also of value in preventing scoliosis and thoracic deformity. The breathing exercises and shoulder girdle movements should be started on the day following operation and, if properly applied, reduce the incidence of chronic empyemas to a minimum. The patient should be encouraged to move about in bed after the operation and should get up as soon as the general condition allows. He should also be persuaded to be as active as possible as physical exertion hastens re-expansion of the lung.

In this discussion on drainage of acute empyemas, the terms "open" and "closed" drainage have been avoided owing to the varied definition given to them. "Closed" drainage may be used when the empyema cavity is at no time exposed to atmospheric pressure; drainage by an intercostal tube which is connected to a water bottle is an example of this.

No reference has yet been made to the use of decortication in the treatment of acute empyema. Encouraged by the excellent and rapid results given by decortication in some cases of hæmothorax and of chronic empyema a few surgeons have recommended that acute empyemas should be treated by aspiration and sterilization with appropriate antibiotics and subsequently by decortication (p. 325). Such therapy is certainly capable of producing quick and perfect cures but, on the other hand, the results are not uniformly good and decortication must be conceded to be a major operation, whereas rib resection drainage is a minor procedure. It is therefore wise to limit the use of decortication in the treatment of empyemas to those of a chronic type.

Chronic Empyema

There are three types of chronic empyema:

1. Latent, in which the empyema, with or without a bronchial fistula, is not discovered until many months or even years after the acute onset.

2. Persistent, in which the empyema persists for an abnormal length of time after the original drainage. It may be draining more or less completely through the opening in the chest wall or, the opening having

been allowed to heal, the pus may have re-accumulated in the cavity. The treatment of both the latent and persistent varieties is similar and they will be considered together.

3. Tuberculous empyemas.

Causation and prevention of persistent empyemas.—A persistent empyema cavity may be caused by:

(i) The removal of the drainage tube before the cavity is completely obliterated. This is by far the most common cause.

(ii) The persistence of the infection in the empyema cavity, due to:

- (*a*) An unsuspected etiology such as tuberculosis, actinomycosis or pleural carcinomatosis
- (*b*) Failure to provide a sufficiently dependent drainage opening, so that there is a puddle of pus at the bottom of the cavity.
- (*c*) Too long a drainage tube, so that the pus can escape only by overflow, or too short a one, so that there is, between the end of the tube and the cavity, a sinus through which drainage will not readily occur.

(iii) Prevention of expansion of the lung due to pleural fibrosis, caused by:

- (*a*) Failure to remove the fibrin from the cavity at the time of drainage.
- (*b*) Drainage performed too late, that is after the lung has *become bound down under a fibrous covering.*
- (*c*) Drainage performed too early so that the lung collapses and a total empyema ensues.

(iv) Disease of the lung interfering with its expansion, such as bronchial carcinoma, lung abscess, bronchiectasis, etc.

(v) The presence of a broncho-pleural fistula. This is not a common cause as small fistulæ almost invariably close spontaneously after proper drainage of the empyema.

(vi) A foreign body left in the cavity, such as a piece of drainage material or a portion of necrosed rib.

If the routine serial X-ray films taken after drainage show that an acute empyema is not diminishing progressively in size, investigation should be carried out to discover the reason.

If there is still a cavity present three months after drainage, the empyema falls into the chronic category

Operations for chronic non-tuberculous empyema. **Redrainage in a dependent position.**—Patients with a chronic empyema are often suffering from a long-continued toxæmia. They may be anæmic and have often lost a considerable amount of body weight, the tone of the cardiovascular system is often lowered, and amyloid disease may be present. They are, therefore, initially poor subjects for any severe operative procedures. In nearly all cases treatment should be begun by redrainage of the cavity at the most dependent point, taking

the opportunity to obtain a piece of parietal pleura for histological examination. The site for redrainage is determined from "pleurograms" obtained by the method described under actute empyema. Sometimes there is a sinus leading to the bottom of the empyema cavity but this should not be dilated up with bougies in order to introduce a tube of a calibre sufficiently large to provide adequate drainage, as there is evidence that this may cause the occurrence of a brain abscess. In such cases it is preferable to provide drainage by excising the sinus and making an adequate opening into the cavity by incision, as this provides the opportunity to make a biopsy of the pleura and to examine the cavity and exclude the presence of a foreign body. If it is particularly desirable to avoid an operation the sinus may be dilated by introducing a laminaria tent for 24 hours, as this method of dilatation does not appear to increase the incidence of brain abscess.

If, after providing dependent drainage, breathing exercises are carried out and the patient is persuaded to become as physically active as possible, the lung will frequently expand and further operation is thus rendered unnecessary. The re-expansion may be very slow but there is no need for the patient to remain in hospital during the period of re-expansion and it is frequently possible for him to return to work with the tube *in situ*.

Some surgeons believe that obliteration of the empyema cavity may be hastened by applying a high negative pressure, by means of an electric pump, to the tight-fitting drainage tube. The negative pressure should always be measured and a leak valve should be inserted, so that the pressure cannot become more negative than that decided upon. Minus five centimetres of Hg may be used at first, rising to minus fifteen if bleeding or pain does not occur. It is doubtful if this negative pressure does more than cause an œdema of the walls of the cavity and it probably has very little value in aiding obliteration of a chronic empyema.

If expansion of the lung does not follow redrainage, further operation should be postponed until the condition of the patient warrants it.

An empyema is not healed until the visceral and parietal layers of the pleura have come into contact *and united*. Obviously it is much better to accomplish this by getting the lung to expand than by bringing the chest wall down in contact with the partially collapsed lung. Ideally, therefore, decortication which is designed to free the lung so that it may expand is much preferable to the various modifications of thoracoplasty which are designed to mobilize the chest wall so that it can come into contact with the visceral pleura.

Decortication.—As the lung is, so to speak, imprisoned by its fibrous coat, it may expand and fill the chest cavity if this layer of fibrous tissue is removed. The removal, or decortication, which is described on p 325 under hæmothorax, is an ideal procedure but, technically, it may be very much more difficult than in the case of a chronic hæmothorax, as the infection often makes the plane of cleavage very adherent. The duration of the empyema is not an important

factor influencing the ease with which the fibrous tissue can be separated, as it is sometimes as readily stripped from a cavity of many years standing as it is from one only a few months old.

Decortication should be attempted in all large chronic empyemas, that is, those which extend under five or more ribs, for there is considerable deformity and limitation of respiratory function if one of the collapse procedures is employed with these large cavities. Decortication is particularly suited to those cases of chronic empyema which have been caused by prolonged treatment of the acute phase with intrapleural penicillin and in which no drainage has been provided, as the contents of the cavity have usually been sterile for a considerable time and the fibrous walls are therefore not so densely adherent.

The technique of decortication for a chronic empyema and the post-operative care do not differ from those used for a chronic hæmothorax although, as previously mentioned, the separation of the scar tissue in an empyema is likely to be very much more difficult: in some cases the difficulties may be so great that the procedure has to be abandoned and a plastic operation on the chest wall performed in its stead.

A systemic course of penicillin or other antibiotic is usually given during the first ten days after operation on the supposition that this may decrease the incidence of infection in the space between the lung and chest wall.

Thoracoplasty.—The closure of a chronic empyema cavity by a plastic operation on the chest wall must never be contemplated until the cavity has been really adequately drained for many months because even cavities that have persisted for many years may clear up when properly drained. A second and equally important reason for delaying thoracoplasty is that these patients are frequently suffering from chronic toxæmia, and the condition of the patient will be much improved by adequate drainage and general treatment. Thoracoplasty should not be used for large chronic cavities except in those cases where decortication has proved impracticable.

The ordinary operation of thoracoplasty, that is, simple decostalization, is not sufficient in chronic empyema because the thick rigid fibrous tissue on the parietal pleura will still keep the cavity open after the ribs have been resected. Therefore, after removing the ribs overlying the cavity, it is necessary either to resect the parietal layer of fibrous tissue together with the intercostal structures (Schede's " de-roofing " operation) or to mobilize these tissues so that they form a plastic flap which can be brought into contact with the visceral pleura (Roberts's flap operation). Large empyemas in which decortication has failed and moderate sized cavities, that is, those underlying three or four ribs, should be treated by Roberts's operation. Small residual sinuses, particularly if there is a bronchial fistula present, are preferably treated by the " de-roofing " operation.

Roberts's flap operation.—In the case of large cavities where decortication has failed, the operation must be performed in two, or

sometimes three, stages, as it is rarely possible to do the whole operation in one sitting without risk to the patient's life. In one, two or three stages, according to the size of the cavity, the ribs overlying it are resected subperiosteally.

The stages of decostalization proceed from above downwards, and the drainage hole in the chest wall is sealed off at the time of operation, so that with precaution the wound does not become infected from the sinus. (For details, see Thoracoplasty, p. 409.) If the cavity is

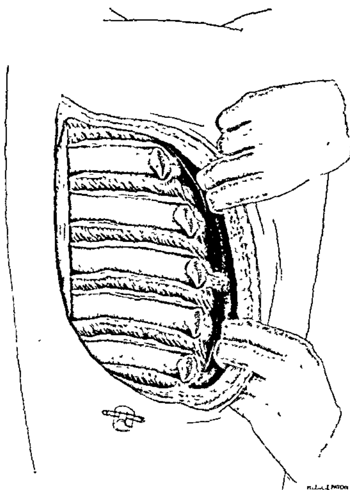


Fig. 126.—Diagram showing decostalization over a chronic empyema cavity.

moderate in size, that is, only extends under three or four ribs, the decostalization and formation of a flap may all be done in one stage.

The ribs must be resected well beyond the margins of the cavity (*Fig.* 126); when it lies posteriorly the resection must be continued back to the transverse process, and when the cavity extends nearly to the apex the first rib must be taken. As the intervals between the stages of decostalization may have to be two weeks or more, the regeneration of the ribs should be delayed by rubbing the periosteum with 10 per cent. formalin. At the final stage, the wound is reopened

and a flap is made of the outer wall of the cavity (Fig. 127). In order to avoid interrupting the blood supply of this flap the cavity is incised along its anterior margin. This includes division of the intercostal vessels, which are ligated The incision is continued round the apex and base of the cavity in such a way that the *thickened* parietal layer with the overlying intercostal muscles and periosteum form a flap that is hinged posteriorly.

The whole of the lining of the cavity is now rubbed firmly with dry

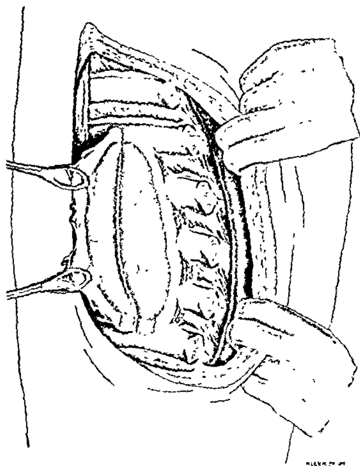


Fig. 127.—Diagram of posterior hinged flap made from the outer wall of the empyema cavity.

gauze so as to remove the soft granulation tissue. Where the visceral layer of thickened pleura runs into the parietal layer posteriorly, a wedge of fibrous tissue is resected to allow the chest wall flap to hinge inwards so that it will lie with the whole of the parietal surface in contact with the visceral, for if these two surfaces can be maintained in contact they will adhere, and obliterate the cavity.

After covering the walls of the cavity with a thin layer of penicillin powder, vaseline gauze is placed on the outer surface of the chest wall flap so as to hold it down. The musculo-cutaneous flap is next drawn together on the outer surface of the pad of gauze and maintained in

place with a few sutures (Fig. 128). Another pad of gauze is placed on the outer surface of the skin, and the chest wall is strapped firmly with adhesive plaster. Seven to ten days later the wound is reopened and the vaseline pack that lies under the musculo-cutaneous flap is removed; the wound is then resutured loosely, and a corrugated rubber drain left in for a few days. This operation yields a higher percentage of cures than any other plastic procedure and, in large empyemas, the final deformity is less marked than after the "de-roofing" operation.

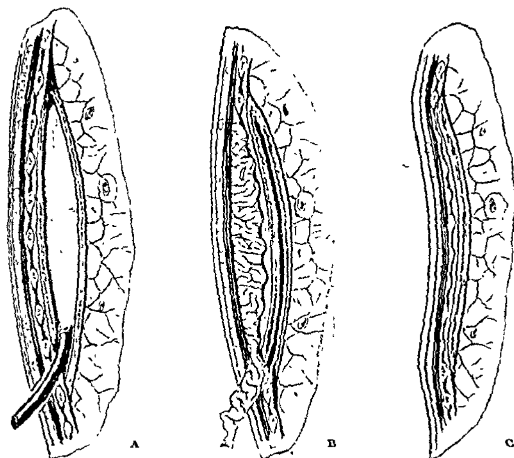


Fig. 128.—(A) Longitudinal section through chronic empyema cavity before thoracoplasty. (B) The operation completed; the gauze pack is seen lying deep to the skin and extracostal muscles. (C) The *end result, viz., complete adhesion between the* visceral and parietal layers of pleura.

Schede's "de-roofing" operation.—The initial steps of this operation are similar to those described for the flap operation, but, when the stage of opening the cavity is reached, the chest wall flap consisting of the thickened parietal pleura, intercostal muscles and bundles and periosteum is excised completely instead of being utilized to help fill the empyema cavity. If there is a bronchial fistula present, the margins of the opening should be excised so as to remove the bronchial epithelium and the lumen closed with a stainless steel wire suture. To reinforce the closure of the fistula an intercostal bundle

may be divided anteriorly and freed backwards so as to form a cylindrical muscle graft with its pedicle placed posteriorly: the free end of the graft is then sutured over the site of the fistula. Small fistulæ do not require closure by suture as they almost invariably heal spontaneously.

Any part of the cavity which cannot be obliterated with the musculo-cutaneous flap is covered with a thin film of penicillin powder and packed with dry gauze. Those parts of the skin edge which come into contact with the pack should be protected with a thick layer of vaseline to prevent adherence and so lessen post-operative pain. The pack is removed after seven to ten days and the cavity is repacked with dry gauze: this dressing may require a short anæsthetic if the gauze is very adherent to the raw area. Subsequently the wound is packed each day with dry gauze and allowed to heal from the bottom by granulation tissue. This operation gives good results, but those cases in which the chronic empyema cavity extends into the para-vertebral gutter are the least suitable as it is difficult or impossible for the musculo-cutaneous flap to fall into this region. Unfortunately the paravertebral gutter is a common site for a residual empyema.

Tuberculous Empyemas

The treatment of tuberculous empyemas is complex as there is no single line of treatment which is suitable to all cases. The subject is made considerably more difficult by the diverse opinions which may be expressed on the proper treatment of an individual case.

A tuberculous empyema may develop spontaneously or, more frequently, it develops during the course of treatment by artificial pneumothorax, particularly if the collapse is maintained without control of the pulmonary lesion and also after adhesion section in cases unsuited to this operation. In considering the treatment of tuberculous empyemas it is necessary to divide the cases into several categories based on (1) the presence or absence of secondary pyogenic infection and (2) the presence or absence of a bronchial fistula.

The nature and extent of the underlying pulmonary disease also influences treatment and reference is made to these factors under each category.

A. Pure tuberculous empyemas without a bronchial fistula.—(1) The pus should be aspirated through the axilla leaving a mean negative pressure of about 8 cm. of water in order to encourage the lung to re-expand. The whole aim of treatment is to obtain re-expansion of the lung as, if this is achieved, the pulmonary lesion can usually be treated successfully. The aspiration should be repeated as often as the pus recollects in an amount sufficient to interfere with pulmonary re-expansion. The time taken for such recollection of pus varies greatly so that some cases require aspiration at least once a week whereas others may be left for a month or more If simple aspiration does not lead to progressive re-expansion of the lung, it is possible that

the rapidity with which pus reforms may be reduced by the intrapleural injection of 5 gm. of *para*-aminosalicylic acid (" P.A.S.") or, alternatively, of 2 gm. of streptomycin at the end of each aspiration. It is doubtful, however, if either of these drugs have much effect when injected into a tuberculous empyema.

If difficulty is experienced in aspirating the pus due to its viscosity or to particles of fibrin, this may be overcome sometimes by the use of streptokinase and streptodornase, as described for cases of clotted hæmothorax (p. 324). Alternatively or in addition the empyema cavity may be washed out with normal saline.

A " pleural wash-out " is performed by inserting an artificial pneumothorax needle through the second space anteriorly and connecting this to an artificial pneumothorax apparatus. A second needle of large bore (17 B.W.G.) to which a two-way adaptor is attached is inserted low in the axilla and as much pus as possible aspirated through it, the pleural pressure meanwhile being adjusted by allowing air to enter through the upper needle. The lateral opening in the two-way adaptor is now connected by rubber tubing to the vessel containing the irrigating fluid (the standard flask used for intravenous therapy is particularly suited to this purpose), and the fluid is allowed to flow into the empyema while the air escapes through the upper needle. The fluid is subsequently withdrawn in a manner similar to that used initially for aspirating the pus. These processes are repeated until the aspirate is relatively clear. It is doubtful if pleural wash-outs which were extensively used in the past are really of much value.

(ii) If it is found impossible to obtain re-expansion of the lung the choice lies between (*a*) thoracoplasty, (*b*) decortication, (*c*) lobectomy and decortication of the remaining lobe and (*d*) pleuropneumonectomy followed by or combined with thoracoplasty. If it is known that the disease in the lung involves both upper and lower lobes and if there is evidence that this disease has been controlled by the collapse associated with the empyema, thoracoplasty (p. 409) should be used to obliterate the empyema but it will be necessary to aspirate the pus between stages so that the chest wall may fall into contact with the lung.

If the pulmonary disease is known to have been of minor extent and is considered to have healed, it is reasonable to attempt decortication (p. 325) so that the lung may re-expand and function again.

If the disease in the lung is known to have been limited to one lobe, the diseased lobe should be removed (p. 373) and the thick pleura stripped from the surface of the remaining healthy lobe and from the chest wall. A successful operation of this type gives the same end-result as a lobectomy performed in the absence of an empyema, for the decortication leaves the remaining lobe free to expand so as to fill the hemithorax.

If the pulmonary disease involves both lobes and appears likely to remain unhealed even after thoracoplasty, pleuropneumonectomy should be performed and a thoracoplasty done either at the termination of this operation if the patient's condition permits or, if not, at a later

date. The operation of pleuropneumonectomy combines removal of the lung (p. 366) with removal of the thickened diseased pleura from the diaphragm and chest wall as described under decortication.

It is worth emphasizing here that a surgeon should be most determined in his efforts to avoid tube drainage of a pure tuberculous empyema, as drainage often leads to an increase, and not a decrease, in toxæmia, and secondary infection is certain to follow sooner or later.

B. Pure tuberculous empyema with a bronchial fistula.—If there is a bronchial fistula present permitting expectoration of the pleural pus, secondary infection of the empyema and bronchogenic spread of the pulmonary disease is certain to occur sooner or later. Treatment is *therefore urgently required. Aspiration and local chemotherapy (but not* pleural wash-outs) may be tried for a short period provided the empyema is kept sufficiently dry to prevent expectoration of its contents. Occasionally the fistula heals and the case may then be treated as already described under category " A." If the fistula does not heal within three or four weeks, the choice lies between thoracoplasty *preceded* by external drainage, removal of the lobe bearing the fistula combined with decortication of the remaining lobe, and pleuropneumonectomy combined with or followed by thoracoplasty. In deciding which of these alternatives to select, the surgeon will be influenced by the same factors as those which were considered in choosing the right operation for cases without a fistula.

If thoracoplasty is decided on, the empyema must first be drained externally so that there is no pus to enter the fistula while the patient is in the lateral position for the thoracoplasty. If the patient is seriously ill the drainage may be performed initially by the insertion of an intercostal catheter (p. 331) but it is usually necessary to follow this with rib resection (p. 333) in order to avoid pain from pressure on the intercostal nerve. With regard to the site for drainage, many surgeons recommend inserting the drain low in the axilla as it is claimed that posterior drainage makes it more difficult to obtain a clean thoracoplasty wound. Actually it is easier to perform an adequate thoracoplasty and to keep the incision away from the drainage tube if the latter is placed low down posteriorly. The thoracoplasty consists in simple decostalization and it will be found that this frequently leaves a residual sinus leading to the bronchial fistula. The residual sinus may be closed by Roberts's flap operation or by Schede's de-roofing procedure but neither of these should be attempted until the tuberculous infection has become dormant, that is, two to three years after the original thoracoplasty.

C. Tuberculous empyema with secondary pyogenic infection but no bronchial fistula.—In these cases the secondary infection can nearly always be eradicated by the repeated intrapleural injection of an appropriate antibiotic, such as penicillin, as described in the treatment of pyogenic empyemas (p. 331). When the secondary invaders have been destroyed, the case may be treated as a pure tuberculous empyema (*see* category " A ") In those rare instances where the secondary

infection persists in spite of intrapleural chemotherapy, the empyema must be drained externally. Subsequently, when the patient is fit enough, it is almost invariably necessary to perform a thoracoplasty as the lung very rarely expands so as to obliterate the empyema.

D. Tuberculous empyema with secondary infection and a bronchial fistula.—Destruction of the secondary invaders by intrapleural chemotherapy is worth trying although this is more difficult to achieve than in those cases in which there is no fistula and, even if they are destroyed, reinfection with pyogenic bacteria is likely to recur after a short interval. If the secondary infection is successfully eradicated, the case may be treated as described under category " B." If the pyogenic bacteria persist, it is necessary to drain the empyema externally and follow this with thoracoplasty. There may be a residual empyema cavity after the thoracoplasty but this can usually be closed later by a further plastic procedure when the tuberculous infection has died out as recommended under category " B ".

In the above synopsis, thoracoplasty has been recommended whenever external drainage has been employed. Occasionally a successful result may be obtained after external drainage by removing the diseased lobe and decorticating the remaining healthy lobe or by pleuropneumonectomy if the whole lung is diseased, but the presence of external drainage certainly makes it more difficult to obtain a good result from resection.

None of the major surgical procedures recommended above can be carried out unless the general health of the patient and the condition of the opposite lung are satisfactory.

OPERATIONS ON THE LUNG

External Drainage of Lung Abscess

Since the introduction of the antibiotics, there has been a decrease in the incidence of lung abscess and many cases have been cured by intensive antibiotic therapy combined with postural drainage. To be successful both drug and postural treatment must be started at an early stage in the evolution of the abscess and continued until the infection has been completely destroyed which usually means for at least four weeks. External drainage therefore is not practised so frequently as in the past but it is still required for those cases which do not respond quickly to chemotherapy and it is essential that the operation should not be delayed until there is much fibrosis and secondary bronchiectasis. An abscess which is not showing all the signs of progressing to cure at the end of three weeks' medical care probably requires external drainage, particularly if the cavity is large. This does not apply to staphylococcal abscesses for which drainage should be avoided if possible as they show a remarkable capacity to heal on prolonged conservative treatment. If there are already gross secondary changes in the lobe containing the abscess, the patient can only be cured by resecting the affected lobe. There is no doubt that resection is tending to replace external drainage in the treatment of patients with a lung abscess which has failed to clear up with medical treatment. In fact, where there are

facilities for major intra-thoracic surgery, external drainage has almost become an obsolete operation.

Principles of external drainage.—(1) The exact localization of the abscess before operation is of the utmost importance, so that it may be opened at the site where it reaches the surface of the lung. As a pulmonary abscess is a lesion which primarily affects a single segment or subsegment of the lung, accurate localization is greatly facilitated if the surgeon is familiar with segmental anatomy and with the distribution of these segments in relation to the chest wall.

The signs derived from physical examination by the ordinary clinical methods are sometimes of great value in localizing an abscess but, unfortunately there may be no physical signs at all so that localization then depends entirely on radiography and bronchoscopic examination.

Every patient with a lung abscess should be examined by bronchoscopy in order to exclude the presence of bronchial obstruction by a foreign body, growth or other lesion: during this investigation the orifices of the segmental bronchi should be examined carefully in order to determine from which segment the pus is derived, as this knowledge will help in deciding which part of the chest wall is in closest proximity to the abscess.

Localization of the abscess depends to a great extent on proper X-ray examination, and a lateral view as well as a postero-anterior film is essential: in some cases oblique views and fluoroscopy will aid in determining the position of the abscess. The most certain method of localization is tomography, both in the antero-posterior and lateral views. In difficult cases valuable information may sometimes be gained by injecting 1–2 ml. of iodized oil to which a little gentian violet has been added into the intercostal space considered to lie in closest relation to the abscess, and subsequently taking further X-ray films. The gentian violet is added to the oil so that the site of the injection may be recognized when operating to drain the abscess If doubt still exists as to the exact position of the abscess, X-ray examination after the introduction of iodized oil into the bronchial tree may help to localize the abscess by showing an area into which the iodized oil does not enter. On no account should aspiration be employed for localization before the operation, as this may be followed by an empyema.

The importance of accurate localization cannot be over-emphasized.

(2) There must be firm adhesion between the two pleural surfaces in the field of operation before the lung is opened. If the abscess is situated in apposition to the chest wall and is exposed by resection of a portion of rib immediately overlying it, adhesions are almost certain to be present and the abscess may be opened forthwith without risk of producing a pneumothorax. However, before incising the lung, the pleura should be inspected most carefully and, if it is thin and the lung is seen to glide up and down against the parietal pleura on respiration, the opening into the abscess must not be made immediately but must be postponed until the two pleural layers are firmly adherent. This means converting the operation into two stages, the object of the first being the formation of pleural adhesions over the area of lung to be subsequently incised. If there is the slightest doubt regarding the adherence between the two pleural layers, the operation should always be done in two stages.

All putrid lung abscesses are situated in the periphery of the lung, and therefore in contact with the visceral pleura, but the " periphery of the

lung" includes the lung tissue adjacent to the interlobar fissures, the mediastinal pleura and the diaphragm: when an abscess occurs in one of these latter situations, although pleural adhesions are present, there may be no adhesions between the lung and the chest wall through which drainage is to be performed. Drainage must then invariably be done in two stages. It is, however, rare to discover an abscess which has no contact with the chest wall. Another reason advanced in favour of two-stage drainage is the danger of causing an extensive infection of the chest wall if the pus from the abscess is brought into contact with the tissues before a barrier of granulations has developed. This risk was never great and is now almost excluded by the local application of penicillin powder.

(3) The opening into the abscess should be sufficiently large to allow the removal of sloughs and provide a clear view of the walls of the cavity. If the cavity cannot be packed easily with a 2 in. gauze roll, the opening is too small and must be enlarged. This is particularly important as secondary hæmorrhage is not an uncommon complication of a putrid lung abscess but it can usually be controlled by packing the cavity firmly with dry gauze. On the other hand it is unwise to resect several ribs and "de-roof" or "saucerize" the cavity, as this is likely to be followed by multiple persistent bronchial fistulæ opening on to a surface covered by bronchial epithelium which bridges the deficiency in the chest wall.

Technique.—The position of the patient is that which gives easiest access to the area to be operated on; it is preferable to have the table in slight

of the putrid pulmonary infection by inhalation of pus or infected blood is thus avoided. Further, if there is severe bleeding from the wall of the abscess cavity, the patient can usually maintain an adequate air-way by expectorating the blood until the hæmorrhage is controlled. The site of the incision depends on the position of the abscess, and it should be of sufficient extent to permit, in the adult, the resection of 3 in. of the rib which overlies the centre of the abscess cavity. Having completed the rib resection the periosteum which lay on its deep surface should be incised so as to expose the parietal pleura, taking the utmost care not to puncture the pleura. With a blunt instrument or finger the periosteum and the intercostal bundle and muscles are freed from the parietal pleura as far as the rib below. After ligating the vessels at each end of the incision the intercostal tissues are excised (Fig. 129). A small additional area of parietal pleura may be exposed by removing the intercostal muscles above the site of the excised rib, being careful to avoid injury to the intercostal vessels lying below the rib above. If there are firm pleural adhesions the surgeon may proceed now and open the abscess. If there does not appear to be firm adherence between the two layers of pleura, the wound is packed open with dry gauze after protecting the wound edges with a thick layer of vaseline. The gauze pack causes sufficient irritation to create adhesion between the two layers of pleura after seven to ten days although some surgeons believe that gauze soaked in tincture of iodine is more effective in promoting adhesions. If a piece of lead wire enclosed in rubber tubing is placed around the margins of the prepared area of pleura, radiograms of the chest taken in two planes before the second stage will show clearly

the relation of the prepared area to the cavity. At the second stage seven to ten days later, after removing the gauze and making sure that the two pleural layers have adhered, the abscess is drained. The technique of opening the abscess is the same for both the one and two stage procedure.

The lung is explored with a large-bore needle to find the exact position of the pus before incising the lung. If the abscess is draining through the mouth, it may contain only gas, which will be withdrawn into the syringe, and has a peculiarly foul odour, which distinguishes it from air that may have been aspirated from a bronchus. As soon as pus or offensive gas is drawn into the syringe, it is wise to leave the needle *in situ* so that it may act as a guide to the abscess cavity. For excising and removing the tissue over the abscess, the most satisfactory method is to use a diathermic current or the actual cautery at dull red heat, so as to control hæmorrhage. At the same time the assistant employs aspiration in order to keep the lung field dry. The opening into the abscess should be rather more than an inch in diameter. Any sloughs present should be removed with sponge-holding forceps and the cavity freed of pus by aspiration with the sucker. The walls of the abscess can then be inspected and any auxiliary pockets opened into the main cavity. Occasionally it is necessary to remove a segment of the rib above or below and excise the associated intercostal structures in order to provide adequate access to the cavity. The abscess is packed with dry gauze after covering its wall and the exposed tissue with a thin layer of penicillin powder. The margins of the wound should be smeared freely with vaseline to prevent the gauze adhering to the skin edges. No sutures should be applied to the skin or to the muscles of the chest wall, as the main difficulty is to keep the superficial tissue from closing before the lung itself has healed.

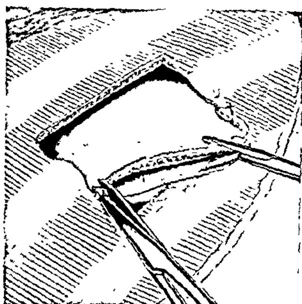


Fig. 129.—External drainage of lung abscess.
A portion of rib has been resected and the intercostal bundle is about to be excised.

Post-operative treatment.—The dressings are left undisturbed for several days after operation. If the fœtor is not too offensive and if the patient does not expectorate large quantities of pus consequent to saturation of

the gauze pack, the first dressing, may be delayed for as much as a week. It should be done in the operating theatre where suction and proper illumination are available. Subsequently the dressing, including the gauze pack in the abscess, should be changed every 24 hours, and this may be done in the ward if there was no bleeding at the time of the first dressing. If removal of the pack during the early stages of convalescence causes much pain, the dressings may be done less frequently at this time. If the cavity is insufflated with penicillin powder at each dressing, the discharge very quickly ceases to be fœtid. The cavity should not be packed tightly but sufficiently firmly to bring the gauze into contact with all parts of the abscess wall. On the other hand, the wound in the chest wall should be packed very firmly in order to maintain an adequate opening into the cavity. If, in spite of this, there is still a cavity in the lung when the opening in the chest wall has shrunk to a degree that it is difficult to pass the gauze through it, attempts to pack the cavity should be abandoned: drainage must then be provided with a rubber tube which is fixed in position so that the inner end just enters the cavity. It is essential to employ some form of drainage as long as there is a cavity in the lung. If it is impossible to see into the bottom of the wound and there is still a bronchial fistula present, the progress of the cavity may be assessed from X-ray films taken after packing it with a narrow gauze roll which has been previously wrung out after immersion in iodized oil.

The patient should lie on the affected side as much as possible so that the pus may escape through the drainage opening, instead of being aspirated into the healthy side. The expectoration of any material which escapes into the bronchial tree should be encouraged.

The general treatment of the patient requires especial attention. Abundance of fresh air is advisable, and blood transfusion will frequently be found advantageous. Unlike cases of empyema there should be no hurry to get these patients out of bed. The time taken for the cavity to heal varies from six weeks to six months, depending on the duration of the abscess before drainage, and, to a lesser extent, on the size of the cavity. It a cavity is still present at the end of six months, there is almost certainly so much fibrosis and secondary bronchiectasis that a cure will only be achieved by resecting the diseased portion of lung.

Post-operative dangers and complications. [illegible] complication. Those nursing the patient [illegible] informed how to deal with the hæmorrhage [illegible] doctor. A sterile package, containing a six-yard roll of gauze and two long artery forceps should always be kept beside the patient's bed. As soon as the patient starts to cough blood, the dressings are rapidly removed and the lung wound packed tightly with the dry gauze under the guidance of the eye. If a definite area of the wound can be seen to be the origin of the hæmorrhage, it is sometimes possible to pass a suture ligature round it. The pack may be removed in the operating theatre 48 hours later. If the hæmorrhage recurs the same treatment is adopted. Less frequent dressing are not usually more effective in terminating the hæmorrhage as they encourage persistence of the septic process which is responsible for the sloughing of the vessel wall and consequent hæmorrhage.

(2) *Spread of infection in the lung.*—Small pockets of pus not discovered at the time of operation may keep up the infection in the lung. It may be possible to open these loculi into the main cavity and obtain a satisfactory

result, but usually these multilocular cases require resection. Spread of the infection into other parts of the lung should be treated promptly by a systemic course of a suitable antibiotic.

(3) *Broncho-cutaneous fistulæ.*—Fistulæ following the drainage of a lung

the openings by painting them with solid silver nitrate, which destroys the epithelium and causes fibrosis; but the majority of these chronic cases cannot be cured without resection of the diseased portion of lung.

Sometimes, when the fistulæ open on to a flat surface, operative closure may be attempted by passing a probe into the fistula and incising the lung round it so that the track, with the probe in it, is isolated. The base of the fistula is then closed with a stainless steel suture and the superficial part excised. The site of closure should be reinforced by a pedicled muscle graft, obtained from the intercostal tissues or from the superficial muscles.

If the fistulæ open into a cavity, resection should be undertaken. Attempts to close these cavities with a pedunculated muscle graft are no longer justifiable as resection is now a relatively safe operation and muscle grafts rarely succeed in their object.

(4) *Brain abscess.*—This is a very serious complication but is not completely hopeless as some patients have been cured by appropriate neurosurgical treatment.

MAJOR THORACOTOMY

A wide surgical opening in the thorax is required for operations such as resection of a whole or part of a lung, repair of diaphragmatic herniæ and removal of many types of mediastinal tumour, and is usually referred to as a " major thoracotomy ".

In this country a postero-lateral approach is employed for nearly all cases but occasionally there may be indications for an anterior exposure (" antero-lateral thoracotomy ") and this will be described separately.

Anæsthesia.—The idea that it is dangerous to open the hemithorax without positive endobronchial pressure in the absence of pleural adhesions or fixation of the mediastinum is incorrect. Nevertheless, a wide opening in the pleural cavity does cause a reduction in respiratory capacity for the reasons explained on page 315. In order to diminish these adverse effects of an open pneumothorax which are greater if the patient is in the lateral position in contrast to the prone or dorsal position, the anæsthetist may either increase the pressure of the anæsthetic gases on each inspiration (" assisted respiration ") or, if this does not reduce mediastinal movement sufficiently, he may abolish spontaneous respiratory movement and ventilate the patient entirely artificially by alternating the pressure of the gases (" controlled respiration "). Obviously respiration cannot be regulated in this way unless general anæsthesia is used. This is most commonly obtained by the intravenous injection of thiopentone and a curarizing agent, repeating the latter as necessary, combined with the administration of equal-parts of nitrous oxide and oxygen using a closed circuit

machine. An endotracheal tube is always employed and ventilation assisted or controlled by alternating manually the pressure on the rebreathing bag. With this method, apnœa may be induced whenever required by increasing the dose of curarizing agent; moderate hyperventilation also helps to abolish normal respiratory movement.

In addition the anæsthetist must prevent bronchial secretions from interfering with the air-way and from spreading to other parts of the lung. For a postero-lateral thoracotomy this problem is solved most simply by operating with the patient in the prone position with the head and shoulders lowered, so that bronchial secretions gravitate along the trachea into the pharynx from which they may be easily removed. In the case of an antero-lateral thoracotomy for which the patient lies on his back, gravity may be used to get rid of secretions by putting a slight Trendelenburg tilt on the operating table. In both types of thoracotomy, suction through a long gum elastic catheter which is passed through the endotracheal tube should be used to assist gravity if the secretions do not run freely into the pharynx.

For operations involving the removal of a whole or part of a lung, an alternative but more complex method of dealing with secretions is to occlude the bronchus draining the diseased area so that the sputum cannot escape from it. This technique makes it safe to operate with the patient in the lateral position. It may be employed with confidence when performing a left pneumonectomy or a lower lobectomy on either side, but it is not reliable for a right pneumonectomy because the upper lobe bronchus arises from the main bronchus so close to the carina that a " blocker " placed in the main bronchus so as to include obstruction of the upper lobe is always liable to slip into the trachea. Consequently when removing the right lung, if the surgeon is not prepared to use the prone position, it is preferable to pass an endobronchial anæsthetic tube into the left main bronchus. When resecting an upper lobe from a patient in the lateral position it is usual to rely on suction to remove the secretions

As a major thoracotomy is usually followed by an extensive intrathoracic procedure, it is wise to insert a cannula or needle into a vein and begin glucose-saline infusion before starting. Blood may then be substituted for the infusion fluid at any time during the operation: this is of great value in maintaining the general condition during a prolonged procedure. In difficult cases blood loss can be greatly diminished by operating after the induction of hypotension by means of the hexamethonium compounds. The relative safety of this manœuvre is still uncertain but it may well be justified when excessive blood loss is anticipated, for example, when performing a pleuropneumonectomy in the presence of an empyema.*

Technique of postero-lateral thoracotomy.—This may be performed with the patient in either the lateral or the prone position. In the former case, the patient lies on his good side with the upper arm pulled

* " Arfonad " (Roche), a thiophanium derivative, has been found to give a safer and more controllable hypotension than the hexamethonium compounds.

upwards and forwards: a soft rubber pad placed under the thorax helps to separate the ribs and increase the exposure when the chest is open (Fig. 130). If the prone position is used, the head, shoulders and pelvis should be properly supported so that the incision may be carried as far laterally as required. The chest is opened either by resecting a long length of one rib or by an intercostal incision. An almost equally good exposure may be obtained without removing a rib by opening the thorax through a rib bed after separating the periosteum from either the lower or the upper border of the chosen rib. This technique has largely replaced the older methods as it subsequently allows nearly perfect restoration of the chest wall. The level at which the opening is made depends on the nature of the proposed intrathoracic procedure. For an operation on the upper lobe

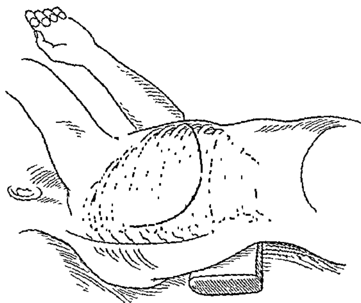


Fig. 130.—Postero-lateral thoracotomy in the lateral position.
The heavy black line indicates the site of incision for exposure of the fifth rib

or superior mediastinum, an approach through the 4th intercostal space or 5th rib bed provides the most satisfactory exposure. For a pneumonectomy the 5th space or 5th rib bed is used, and for a lower or middle lobectomy the 6th space or 6th rib bed. For operations on the diaphragm a good exposure may be obtained by resection of the 8th rib or by an intercostal incision through the 8th space.

The incision runs from the anterior axillary line in front to within an inch of the mid-line posteriorly For a thoracotomy below the level of the 7th rib, the incision may be made directly over the rib or intercostal space to be exposed and the latissimus dorsi and trapezius muscles divided in the line of the incision When the chest is to be opened at a higher level, the skin incision should be made with a deep curve below the inferior angle of the scapula so that the shoulder-girdle muscles may be divided close to their origins, thus avoiding denervation of a large muscle mass below the incision When these muscles have

been severed it is possible to displace the scapula sufficiently upwards and forwards to expose the 5th rib or even the 4th interspace.

The outer margin of the erector spinæ is incised and the muscle separated from the chest wall at the level of the thoracotomy as far back as the transverse processes.

If the chest is to be opened by an intercostal incision, a 2 cm. segment of each of the ribs above and below the chosen space is resected subperiosteally immediately lateral to the corresponding transverse process. The intercostal tissue and parietal pleura are then incised for the entire length of the incision taking care not to injure the underlying lung, particularly when adhesions between the two pleural layers are present. The intercostal vessels associated with the rib above and below the opening are divided between ligatures at their posterior ends in the position where a segment of each rib has been removed.

If the chest wall is to be opened through a rib bed, the selected rib is removed subperiosteally from the tip of the transverse process almost to the costochondral joint (Fig. 131A), and the pleural cavity entered by incising the periosteum and parietal pleura for the full length of the incision. The intercostal vessels associated with the rib removed are then divided posteriorly between ligatures.

Whichever method is used to open the chest, if the operation planned includes removal of both layers of pleura, as, for example, in decortication or in pleuropneumonectomy for tuberculous lesions, the parietal pleura should not be incised but a space developed in the extrapleural plane by blunt dissection

In all intrapleural operations, if there are adhesions between the two layers of pleura in the neighbourhood of the incision, these should be divided so as to free the lung for at least 2 in. on either side of the opening. The margins of the thoracic opening are now protected with very large moist gauze swabs so as to avoid wound contamination and a suitable rib spreader is inserted. The blades of the spreader should be steadily and evenly separated until the opening measures at least 5 in. across at its widest point.

At the end of the operation if the chest was opened through a rib bed, the edges of the wound are drawn together either with hook retractors or by a special rib approximator, and the intercostal tissues above and below the resected rib are united with a continuous nylon suture, which is reinforced with a few interrupted stitches (Fig. 131). With an intercostal incision, before approximating the ribs, pericostal sutures are inserted 1½ in. apart, for the entire length of the wound. The most posterior of these sutures passes through the lateral margin of the erector spinæ, then round the two ribs and back through the erector spinæ again; this is most helpful in closing the posterior end of the wound as it pulls the muscle over the divided ends of the ribs. The pericostal sutures are tied after the ribs have been drawn together with retractors or a special approximator. No attempt to suture the intercostal incision itself need be made after tying the pericostal sutures. Each of the shoulder-girdle muscles should be sutured

separately with continuous nylon and the skin wound closed with the same material.

Technique of antero-lateral thoracotomy.—The patient lies on his back with the arm on the affected side in slight abduction. The

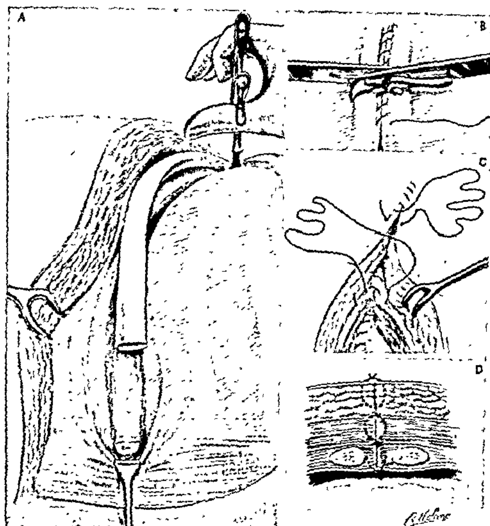


Fig. 131.—Postero-lateral thoracotomy.

A, The rib has been divided posteriorly and is being sectioned with shears close to the costo-chondra junction (but see top of page 354) B, The rib bed is sutured after approximating the ribs above and below the incision. C, Closure of the wound is being completed by suture of the shoulder-girdle muscles and of the skin D, Cross-section of the wound showing the three layers of approximation.

approach is made through an intercostal space* and, for exposure of the hilum of the lung for operations such as pneumonectomy or upper lobectomy, the opening should be made through the third space. The skin incision commences in the mid-line anteriorly on a level with the selected space and sweeps downwards below the breast and is then carried upwards to terminate in the mid-axillary line, again level with the selected space. Those parts of the pectoral muscles which arise

* Alternatively the chest may be entered through the bed of a rib after stripping the periosteum from its lower border

from the chest wall below the site at which it is proposed to open the thoracic cage are divided close to their origins, so that the breast and subjacent pectoral muscles are formed into a flap which is retracted upwards. The pleural space is now opened by dividing the intercostal muscles and pleura in the region of the mid-clavicular line. This incision is subsequently carried as far laterally as possible: in the axilla, branches of the lateral thoracic artery will be found crossing the intercostal spaces superficially and some of these will require division, but injury to the long thoracic nerve should be avoided by retracting it

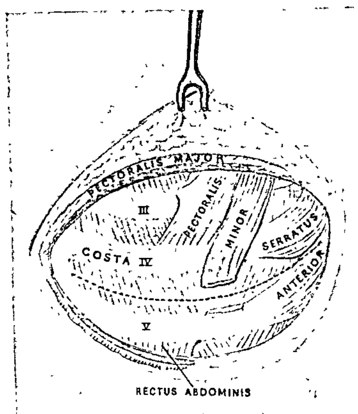


Fig. 132.—Antero-lateral thoracotomy.

The fourth intercostal space has been exposed through a curved sub-mammary incision. The dotted line indicates the site of incision of the intercostal muscles. (Alternatively, the periosteum may be separated from the inferior border of the fourth rib and the pleural cavity entered through the rib bed; if this method is used, subsequent closure of the wound is made easier and more perfect.)

laterally away from the interspace. The incision is then continued medially as far as the internal mammary vessels which lie ½ in. from the lateral border of the sternum. The intercostal tissues overlying the vessels are divided up to the sternum and this may cause some bleeding from anterior perforating branches but this can be controlled temporarily by pressure. If the ribs adjacent to the thoracic opening are retracted forwards and away from the incision, the internal mammary vessels can be gently separated from the posterior aspect of the costal cartilages lying above and below the intercostal incision; these cartilages together with their perichondrium are then divided

with a knife close to the sternum. The internal mammary vessels are now divided between ligatures; the edges of the incision are protected with moist gauze and then separated by the use of a suitable rib-spreader. The separation of the wound edges may be subsequently increased by dividing the intercostal tissues further posteriorly from inside the chest. *To close the wound*, pericostal sutures are used to draw the wound together. If the chest has been entered above the level of the fourth space the intercostal tissues should be approximated as well for the spaces are very wide anteriorly. The divided cartilages may be repaired by transfixing each end with a silk suture which is then firmly tied. It is sometimes necessary to pare away some of the cartilage with a knife in order to make the ends fit snugly. In the author's opinion it is unnecessary to fix the cartilages at all but, if no fixation is used, the ends should be cut so that there is a very small gap between them in order to avoid over-riding. Finally the pectoral muscles are reattached to their site of origin with continuous nylon sutures and the skin closed in a similar manner.

After all thoracotomies, the dressings should be fixed in position with elastoplast strapping so that there is no restriction of respiratory movement. Encircling bandages, such as the many-tail chest bandage, should never be used.

Pneumonectomy

Indications for pneumonectomy. 1. Bronchiectasis.—Unilateral bronchiectasis which involves the lower lobe and all segments of the upper lobe can only be cured by removal of the whole lung. It is most important to appreciate that pneumonectomy inevitably leads to a considerable limitation of cardio-respiratory reserve and should never be performed for bronchiectasis if there are healthy segments which can be conserved. For example, if the bronchial dilatation affects the whole lung *except* the apical and posterior segments of an upper lobe, a pneumonectomy should not be performed for it is possible to remove all the diseased tissue and leave the two normal segments in sole occupation of the hemithorax. If this small amount of lung tissue is saved the functional result is considerably better than would be the case after resection of the whole lung. Therefore neither pneumonectomy nor any other operation for bronchiectasis can be considered until the distribution of the disease has been demonstrated by bronchograms which outline the entire bronchial tree on both sides. The most satisfactory bronchograms are obtained by first taking lateral and frontal radiographs after outlining the bronchi on the right side with iodized oil and, after making a further frontal exposure, films in both oblique positions are taken. It is possible to show clearly all segments in this way but some clinicians prefer to perform bronchography on one side only at a single session in order that lateral views of each side may be obtained without the bronchial trees of the two sides becoming superimposed. But the second side cannot be investigated until nearly all the radio-opaque material has disappeared from the

first side, and although this sometimes occurs quickly, it may take several months. This delay may be avoided by using " Dionosil Oily " (Glaxo Labs.) instead of the standard iodized poppy-seed oil, as " Dionosil " is removed from the lungs within a few days

If the disease on one side is so widespread that it cannot be eradicated without removing the entire lung, it is most important that the contralateral lung should be healthy. Very occasionally it may be justifiable to ignore a minimal amount of dilatation on the opposite side but this is exceptional. There have been a few rare instances in children in which a small localized area of disease on the " good " side has been removed first and a pneumonectomy on the opposite side performed subsequently, but it is doubtful if this radical approach is justified. As children are better able to adjust themselves physiologically to the removal of one lung and as they are better operative risks than adults, there may be less hesitation in recommending pneumonectomy for bronchiectasis in children than in adults. The risk in adults depends more on the duration of the symptoms than on the severity of the disease at the time, for patients who have had suppurative bronchiectasis for many years are enfeebled by toxic changes.

Bronchoscopy should always be performed before undertaking operation in order to exclude a foreign body or neoplasm as the underlying cause of the bronchiectasis.

2. **Chronic lung abscess.**—Very occasionally a large lung abscess which has spread across the interlobar fissure and affected both upper and lower lobes may be an indication for pneumonectomy. Preoperative investigation is similar to that made for bronchiectasis.

3 **Pulmonary tuberculosis.**—The indications for resection in the treatment of pulmonary tuberculosis continue to be controversial, as the operation has not been in general use for long enough to show the late results in a large number of patients. Obviously pneumonectomy is not worth considering unless the contralateral lung is relatively healthy. Ideally, the opposite side should be free of demonstrable disease, but pneumonectomy need not be excluded because of minor lesions in the opposite lung, provided these lesions are free of cavitation and apparently quiescent. Very occasionally, pneumonectomy may be considered in the presence of a shallow contralateral pneumothorax, provided this has controlled the disease in the underlying lung. Removal of the lung may be preferred to other procedures when the whole lung has been completely destroyed by the tuberculous process and in cases showing gross secondary bronchiectasis. Stenosis of the main bronchus, or of the lower lobe bronchus if there is also cavitated disease in the upper lobe, may be accepted as indications for pneumonectomy. If there is cavitation in both lobes and one or more of the cavities are very large, resection of the lung may offer the patient the best chance of being rid of sputum containing tubercle bacilli. Finally, if a thoracoplasty has already been performed for disease

affecting both lobes and has failed to close all the cavities, removal of the lung from beneath the collapsed chest wall is usually preferable to revision of the thoracoplasty in a further effort to close the cavitation by collapse. Reference has already been made to the place of resection of the lung together with the pleura in certain selected cases of tuberculous empyema (p. 344).

If treatment by pneumonectomy is being considered for a patient with pulmonary tuberculosis, bronchoscopy should always be included in the investigation so that a search may be made for tuberculous lesions of the larger bronchi. Before recommending operation it is wise to exclude cavitation on the opposite side by tomographs in addition to ordinary radiographs.

4. **Innocent tumours (adenoma, papilloma, etc.).**—Patients with innocent tumours of the bronchi are rarely seen by the surgeon until there is irreparable chronic suppuration (bronchiectasis or lung abscess) in the lung distal to the tumour. If the tumour is situated in the main bronchus, the patient can then only be cured by resection of the whole lung. In the absence of secondary changes, a satisfactory result may be achieved by removing an innocent tumour which has a narrow pedicle through the bronchoscope, or, in the case of more sessile tumours, by resecting the growth through an incision in the bronchus after performing a thoracotomy. But many innocent tumours are not only sessile but have a large extension outside the bronchus so that if the tumour arises from the main bronchus, pneumonectomy is often the only means of removing the whole tumour. Bronchoscopy is the most valuable investigation in deciding the correct form of treatment, but it is important to realize that an adenoma often projects proximally well above its bronchial attachment and great care must be taken to avoid removing the whole lung in cases where the tumour arises from a lobar bronchus but projects into the main bronchus.

5. **Bronchogenic carcinoma.**—Although the results of resection of malignant disease of the bronchi are disappointing, there is no other form of treatment which offers the patient an equal or better chance of cure or of prolonged palliation. Therefore the possibility of resection must be considered most carefully in every case diagnosed as bronchial carcinoma All operations for malignant disease aim at removing *en bloc* the whole primary growth together with the regional lymphatic glands and intervening lymphatic vessels. In the case of bronchial carcinoma this desideratum can only be achieved by removing the entire lung together with all accessible mediastinal lymph nodes It is tempting to recommend lobectomy for all cases in which the growth is of the peripheral type but this operation does not allow a radical removal of the regional lymph nodes Pneumonectomy is therefore the rational procedure for all operable cases of bronchial carcinoma, whatever the position of the growth, but lobectomy may be recommended for lesions of the peripheral type if the patient's general

condition is such that pneumonectomy would be not only a very hazardous operation but, even if successful, might be expected to leave the patient incapacitated due to breathlessness. In estimating operability, the patient's capacity to withstand the operation must first be assessed. As the disease itself is likely to lead to death within a short time, it is perfectly justifiable to submit the patient to considerable risks, but it is futile to operate on patients with far advanced cachexia or on those with an extremely limited cardio-respiratory reserve.

In those patients considered to have a reasonable chance of surviving the operation and of being restored to an active life, the surgeon must next consider whether there is any evidence that the growth has extended beyond the limits of possible extirpation. Evidence that a growth is inoperable and which may be found without surgical exploration of the chest include:

1. Palpable metastases in the supra-clavicular or axillary lymphatic glands.
2. Clinical signs of obstruction to the superior vena cava.
3. Horner's syndrome or evidence of brachial plexus involvement.
4. Blood-borne metastases in the liver, bones (especially the long bones, vertebræ, ribs and skull), brain or elsewhere.
5. Clinical or X-ray evidence that the growth has extended into a part of the chest wall which cannot be removed surgically. It is, of course, possible and practicable to remove a portion of the chest wall together with the lung but this cannot be done if the growth encroaches upon the vertebral column.
6. The radiographic demonstration of widening of the mediastinum or of secondaries in the opposite lung or of paralysis of the phrenic nerve. (Very rarely the phrenic nerve is destroyed in a position such that total removal of the growth is still practicable.) Extensive mediastinal gland involvement demonstrable by tomography may also be a contra-indication to surgery.
7. The presence of a pleural effusion. This is not necessarily evidence of inoperability as the effusion may be the result of inflammatory changes in the lung distal to the growth. Therefore, if the effusion is transient or if the cytology of the fluid is that of an inflammatory exudate, operation may still be considered.
8. The bronchoscopic demonstration of paralysis of the left recurrent laryngeal nerve, or compression or erosion of the trachea or fixation of the trachea or main bronchi, or widening of the carina, or extension of the growth up to the tracheal bifurcation.
9. Evidence of mediastinal involvement obtained by X-ray examination after taking barium emulsion by mouth. Constant narrowing or irregularity in the outline of the œsophageal lumen are signs of inoperability as they indicate that the growth has extended into the posterior mediastinum.

Pre-operative preparation.—*Pneumonectomy for chronic* suppurative disease should not be performed until the amount of sputum has been reduced as far as possible by a combination of postural drainage and chemotherapy. In patients with large quantities of sputum due to bronchiectasis, postural drainage should be practised for as long as the amount of expectoration continues to decrease, and this may mean many weeks before the patient is ready for operation. In cases of neoplasm

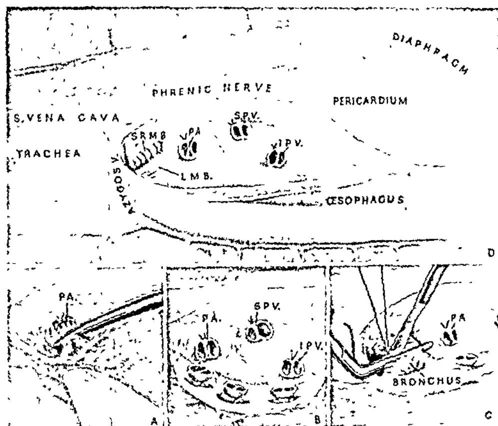


Fig. 133—Right extrapericardial pneumonectomy.

S P V	=	Superior pulmonary vein
I P.V	=	*Inferior pulmonary vein*
S R M B.	=	*Sutured right main bronchus*
L M B.	=	Left main bronchus

complicated by suppuration distal to the growth the general condition can often be improved and the quantity of sputum diminished by a short course of penicillin: this should be combined with postural drainage if the pus is able to pass the obstruction. When tuberculosis is the indication for operation, postural drainage is contra-indicated unless the disease is complicated by secondary bronchiectasis with much pyogenic infection, but it is usual to start a systemic course of streptomycin (1 gm per day) and *para*-aminosalicylic acid (15–20 gm. per day) a week before operation.

In all cases a physiotherapist who has been fully trained in respiratory exercises should teach the patient to improve chest wall movement on the " good side " and to strengthen diaphragmatic action. The physiotherapist should also train the patient to free the bronchial tree of secretions and explain the immense importance of continuing this during the post-operative period. It is obvious that the general condition of all patients should be improved as far as possible: if there is more than a minor degree of anæmia this should be treated by blood transfusion. No advantage is gained by inducing an artificial pneumothorax before operation.

Technique.—The chest is opened through either the 5th intercostal space or the 5th rib bed as described under postero-lateral thoracotomy. This exposure is preferred to the antero-lateral incision as it gives much better access, especially over the lower lobe. The standard method of removing the lung is by an intrapleural operation with the individual ligation of the vessels outside the pericardial sac and suture of the divided bronchus (Fig. 138). This will be described and the various modifications considered subsequently.

The surgeon should aim first at isolating the bronchus and occluding it with a non-crushing bronchial clamp so that there is no further possibility of secretions escaping from the diseased lung into the trachea. The posterior part of the hilum in which the main bronchus lies should therefore be exposed by dividing any adhesions which anchor the lung to the posterior chest wall and mediastinum on a level with the hilum. The adhesions are usually avascular and readily separated but they may be tough and have to be divided between clamps, permanent hæmostasis of the parietal end being obtained by ligature or diathermy coagulation. Sometimes the two layers of pleura are densely fused together, in which case the lung is most easily freed by separating the parietal pleura from the thoracic cage and subsequently controlling hæmorrhage from the chest wall with the diathermy current. As soon as the bronchus is identified, its posterior surface is exposed by incising the mediastinal pleura and dividing the branches of the vagus nerve which pass to the pulmonary plexus; as these branches are frequently accompanied by small vessels it is wise to section them between clamps. The bronchial vessels can now be seen passing from the mediastinum on to the bronchus and these should be clamped, divided and ligated. The bronchus is then freed as high up as possible by blunt dissection from the cellular tissue which surrounds it: it is important to keep the plane of dissection in close contact with the bronchial wall: on the left side, if the pulmonary artery is very adherent to the bronchus, it is wise to isolate the proximal part of the artery before dissecting it from the bronchus.

The bronchus is now occluded with a bronchial clamp as close to the trachea as possible. If the anæsthetist has used a bronchial " blocker ", the bronchus must not be occluded with the clamp until the blocker has been withdrawn by the anæsthetist. When the

patient is in the lateral position the operation is continued by dividing any adhesions between the lung and parietal pleura which prevent access to the main vessels. The pulmonary artery is then isolated and two strong thread ligatures are tied round the artery close to the bifurcation of the main vessel. On the left side the ligatures are placed round the artery immediately distal to the attachment of the ligamentum arteriosum, taking care not to damage the recurrent laryngeal nerve. On the right side, in order to expose the main artery proximal to the origin of the branch to the upper lobe, it is necessary to cut the layer of fascia which passes from the superior vena cava on to the anterior surface of the pulmonary artery: the main vessel which lies in the mediastinum behind the superior vena cava can then be isolated by blunt dissection. After tying the ligatures the artery is clamped at least ½ in. distally and divided close to the clamp. On the right side, in order to leave an adequate " cuff " beyond the ligature, it may be necessary to clamp and divide the upper lobe branch and the main continuation of the artery separately. The superior pulmonary vein is now isolated, doubly ligated close to the pericardium, clamped distally and divided. Subsequently the lower lobe is lifted towards the wound so as to expose the pulmonary ligament: the latter is divided taking care to avoid damage to the lower border of the inferior pulmonary vein. The division of the lowest part of the pulmonary ligament should always be done between clamps as it almost invariably contains a small artery. on rare occasions, this vessel may be very large, being, in fact, an abnormal accessory artery passing to the lower lobe. The inferior pulmonary vein is then isolated and treated in the same way as the superior vein. If the ligatures round the main vessels are tied firmly in the same groove and divided so as to leave a good " cuff " beyond the ligatures, there is no need to place transfixion ligatures before dividing the vessels. If the pulmonary artery is occluded before either of the pulmonary veins (as described above) the lung does not become congested, but, in cases where the presence of the superior vein makes it difficult to expose the artery, there need be no hesitation in dividing the vein first. (*See also* pneumonectomy for carcinoma, p. 366.)

When the vessels have all been divided the lung remains attached only by the bronchus. By applying traction on the bronchial clamp, it is now possible to free the bronchus from the cellular tissue surrounding it right up to the tracheal bifurcation. The bronchus should be divided obliquely ½ cm. from the trachea so that the suture line lies flush with the trachea. This high division of the bronchus is readily accomplished on the right side but often cannot be done on the left without applying considerable downward traction on the bronchial clamp. It is often much easier to divide the bronchus at a lower level but this should not be done as it leaves a stump which forms a diverticulum projecting from the tracheal lumen, so that during convalescence the suture line is frequently bathed in pus which collects in the diverticulum, thus predisposing to the formation of a bronchial

fistula. Each surgeon has his own method of closing the bronchus. The author prefers to divide the bronchus proximal to the clamp and to close the lumen with simple interrupted stainless steel sutures threaded on eyeless needles. The bronchus is not divided at one stroke but the section made in ½ cm. stages, the sutures being inserted and tied as the division proceeds, thus avoiding a large leak of gas from the trachea. With this method there is no contusion of the bronchial wall at the site of suture. Many surgeons prefer to place a clamp obliquely at the origin of the bronchus from the trachea and to divide the bronchus distal to this clamp. The lung can then be removed and the sutures placed round the clamp which is withdrawn before tying the sutures.

Although definite suggestions are made above regarding the order in which the main structures should be isolated and divided, these suggestions are not rigid rules. Thus, if the anæsthetist has complete control over the secretions in the diseased lung, e.g. by a bronchial "blocker", it is often technically easier and safer to isolate and divide the pulmonary artery before freeing the bronchus. Also mobilization of the lung and isolation of the veins are frequently facilitated if the main bronchus is divided between clamps and the bronchus sutured later after the lung has been removed.

Many methods of reinforcing the bronchial suture line have been practised but it has never been shown conclusively that such reinforcement reduces the incidence of post-operative fistulæ. Some surgeons simply draw the neighbouring cellular tissue over the suture line, others cover it with a pedicled flap of parietal pleura, and others fashion an intercostal bundle into a pedicled graft which is sewn over the divided bronchus.

When the patient is in the prone position it is essential to divide the bronchus first in order to obtain proper exposure of the pulmonary artery and the superior pulmonary vein. When these vessels have been sectioned, the inferior pulmonary vein is taken next, and the pulmonary ligament and adhesions between the lower lobe and diaphragm are dealt with last of all.

When the lung has been removed, the pleural space is examined carefully for bleeding points and hæmostasis is perfected. Penicillin powder may then be insufflated over the chest cavity, particularly in the region of the divided bronchus, in order to reduce the risk of post-operative infection. Streptomycin powder (1 gm.) may be introduced in addition in cases of tuberculosis. If the pericardial sac has been opened accidentally no attempt should be made to close the hole. It is usual to crush or divide the phrenic nerve in all patients so that the diaphragm may rise after operation and reduce the size of the pneumonectomy space. This is undoubtedly the right procedure in most cases, but, in elderly patients with a limited respiratory reserve, it is unwise to paralyse the diaphragm and so cause it to move paradoxically during the post-operative period, as this movement is accompanied by a slight shift of the mediastinum towards the

opposite side on inspiration and there is therefore a slight diminution of air entry into the remaining lung. Finally an intercostal tube (about ¼ in. in internal diameter) is inserted through one of the lower intercostal spaces in the posterior axillary line and is connected to a water-seal drain. The chest is closed as described under postero-lateral thoracotomy.

Modifications of the standard operation. 1. *Extra-pleural pulmonary resection (pleuropneumonectomy).* — The extra-pleural separation of dense adhesions has already been mentioned but, in cases of pulmonary tuberculosis where the disease has spread to the parietal pleura, with or without the formation of an empyema, it is necessary to remove all the diseased pleura together with the lung. Therefore, when opening the chest, the parietal pleura should not be incised but should be stripped from the chest wall in a manner similar to that described for decortication (*see* p. 325). The hilar structures are exposed by continuing the separation of the parietal pleura on to the mediastinum. Sarot* recommends that the parietal pleura should be removed completely in all cases of pneumonectomy for tuberculosis, but it is doubtful if there is any advantage in removing portions of parietal pleura which appear completely normal to the naked eye.

2. *Pneumonectomy for carcinoma.*—As soon as the chest has been opened for malignant disease, the surgeon must decide whether resection of the lung together with all visible or palpable growth is practicable. The following conditions must be accepted as evidence that the growth is inoperable:—(1) Neoplastic nodules spread diffusely over the parietal pleura, (2) secondary deposits in irremovable mediastinal glands and (3) extension of the growth into the cellular tissue of the mediastinum or into a part of the chest wall which cannot be removed. Bronchiogenic carcinoma is particularly liable to spread towards the mediastinum around the pulmonary vein draining the lobe which contains the growth. this region must therefore be examined carefully before starting the resection. If the growth has extended as far as the pericardium, the pericardial sac should be opened by an incision placed anterior to the site of invasion and the intrapericardial portions of the veins examined. The case should not be abandoned as inoperable unless it is clearly impossible to section the veins or even the wall of the auricle on the medial side of the growth. Isolation, ligature and division of the pulmonary veins within the pericardial sac is extremely simple as the veins are free except for the reflections of the serous membrane, and it is also easy to develop a plane of cleavage round the artery by dividing the serous pericardium from below (Fig. 184).

There is little doubt that manipulation of the lung is liable to dislodge fragments of growth into the lumen of the pulmonary veins: these fragments thus reach the left side of the heart from which they

* Sarot, I. A., 1949, *Thorax*, iv, 173

are carried into the systemic circulation and are liable to give rise to blood-borne metastases. Consequently handling the lung should be avoided as far as possible until the two veins have been occluded. Also, whenever practicable, occlusion of the veins should be made the

Fig. 134.—Left intrapericardial pneumonectomy.

e dotted line indicates
main vessels have been
The main bronchus,
The appearance of the

first step after opening the chest, that is, before isolation of the artery and bronchus.

As many as possible of the regional lymphatic glands should be removed in one piece together with the lung. Therefore the dissection down to the hilar structures should be made on the medial side of all visible lymphatic glands, and the inferior tracheo-bronchial glands lying below the tracheal bifurcation should be freed from the medial

wall of the opposite bronchus and removed with the specimen. The resection should also include the removal of the glands in the posterior mediastinum close to the attachment of the pulmonary ligament. On the right side, the glands lying to the right and in front of the trachea may be removed after they have been exposed by dividing the azygos vein between ligatures. It has also been recommended that block dissection of the glands in the superior mediastinum should be made when operating on the left side, but the presence of the aortic arch renders this difficult.

Some surgeons use the term "radical pneumonectomy" for an operation which combines block dissection of all accessible glands with intrapericardial division of the vessels, and recommend that this operation should be performed in all cases of carcinoma provided the patient's general condition is adequate to withstand this extensive procedure. However, it is doubtful if intrapericardial division of the vessels is justified if the growth does not extend close to the pericardium.

Post-operative care.—The patient is nursed in the semi-sitting position unless there is evidence of shock which indicates the need for elevating the foot of the bed. After 24 hours the patient should be encouraged to move in bed and he should be rolled on to the side of operation for half an hour each night and morning with the foot of the bed elevated so as to encourage the drainage of secretions from the remaining lung. Oxygen should be administered from the time the patient leaves the operating theatre and should be continued for as long as the patient shows any evidence of suboxygenation when the supply is temporarily interrupted. Frequently, it may be discontinued after a few hours. The incidence of infective complications is probably reduced by giving a course of systemic penicillin which is started the day before operation and continued for at least one week: it may be given for a longer period if there is evidence of infection in the remaining lung or elsewhere.

The rubber tubing which connects the intercostal drain to the water-seal bottle should be occluded with a clamp as soon as the patient has been returned to the ward. It is subsequently released for a few minutes every 2–3 hours so as to allow drainage of any blood-stained fluid which may have collected. It is unwise to allow continuous drainage as this often leads to gross shift of the mediastinum towards the side of operation as a result of the air being expelled through the tube whenever the patient coughs or strains. The intercostal tube is removed after 48 hours unless there is much hæmorrhagic discharge indicating the need for prolonging the period of drainage. The hemithorax then gradually fills with blood-stained fluid which subsequently deposits fibrin and this later organizes so that the ultimate outcome is a hemithorax much reduced in size by shift of the mediastinum, rise of the diaphragm and contraction of the chest wall, and containing a mesh-work of fibrous tissue with fluid in the meshes. Occasionally an excess of bloody fluid collects after the tube has been

removed and displaces the mediastinum to the opposite side. It is therefore essential to follow the early post-operative course with frequent radiographs so that an excess of fluid may be recognized at once and treated by aspiration. Some surgeons recommend that the fluid should be kept below the level of the sutured bronchus for the first two weeks in case a bronchial fistula develops, but it is doubtful if this is necessary if the patient's progress is quite uncomplicated. The risk of infection of the pleural space may be reduced by injecting a million units of penicillin into it at the time of removing the drainage tube and repeating this about three days later.

Breathing exercises which the patient has learnt during the pre-operative period should be recommenced on the day following operation and continued until the patient is discharged from hospital. The nursing staff, as well as the physiotherapist, must persuade the patient to expectorate all sputum; the importance of keeping the bronchial tree free of secretions cannot be over-emphasized. The patient cannot be expected to cough adequately during the first two or three days without the help of anodyne drugs; an opiate or pethidine should therefore be given in sufficient quantity to relieve the pain of coughing but the dose should not be large enough to interfere with the cough reflex.

In tuberculous cases, in order to reduce the likelihood of tuberculous infection of the bronchial stump and to prevent spread or reactivation of the disease in the opposite lung, the systemic course of streptomycin (1 gm. per day) and *para*-aminosalicylic acid (15–20 gm. per day) which was started a week before pneumonectomy is continued for 6 weeks after operation.

The post-operative management of the pneumonectomy space has already been outlined but many surgeons consider that the method described is not suitable for cases in which pulmonary tuberculosis was the indication for resection. It is argued that the enlargement of the contralateral lung caused by the shift of the mediastinum towards the side of operation increases the likelihood of reactivation of any remaining tuberculous lesions. It is also claimed that there is a considerable risk of tuberculous infection arising in the pneumonectomy space, either as an early post-operative complication or at any time later, even after an interval of several years. In order to avoid these dangers, it is advised that the space should be obliterated or at least reduced in size by some form of thoracoplasty (for general technical details, *see* p. 409). If the patient's condition is excellent after completing the resection, a few surgeons recommend extending the posterior end of the incision upwards and completing the 7-rib thoracoplasty straightway but this leads to much post-operative paradoxical movement and is rarely justified. On the other hand it is often justifiable to remove the posterior half of the 6th rib and a somewhat shorter segment of the 7th rib so that completion of the thoracoplasty about 4 weeks later only involves removal of the upper 4 ribs.

The thoracoplasty is often described as being " tailored ", meaning

that the mobilization of the chest wall is adjusted to the size of the space to be obliterated. Most commonly segments of the 2nd to *the 7th rib inclusive are removed* and the periosteum is freed from the entire under surface of the first rib. The first rib is thus preserved in order to lessen the deformity consequent to the thoracoplasty. The author prefers to remove the whole of the first rib, as its preservation appears to make no difference to the deformity but does lessen the chance of obliteration of the apical part of the pneumonectomy space. The length of each rib removed is graded from above downwards, that is, nearly the whole of the 2nd rib is excised and progressively shorter segments of the ribs below, finishing with about 5 in. of the posterior end of the 7th rib.

In feeble patients in whom no decostalization was done at the time of pneumonectomy it may be necessary to divide the decostalization into two stages. *Some surgeons deliberately open the pneumonectomy* space when performing the thoracoplasty and evacuate the contents so that the mobilized chest wall may collapse on to the mediastinum.

It is not yet certain that routine post-pneumonectomy thoracoplasty will in fact improve the results of resection for tuberculosis. Therefore, *unless the stability of the disease in the opposite lung is in doubt* or there is definite evidence that tuberculous infection of the space is a serious contingency, as, for example, in cases where the pulmonary disease is complicated by obvious extension to the pleura, the author prefers to manage the pneumonectomy space in a manner similar to *that applied to non-tuberculous subjects. Some authorities maintain* that thoracoplasty should be performed after pneumonectomy on the right side, but that it is unnecessary after left-sided resections because the rise of the diaphragm on the left is usually greater than on the right and because the heart and mediastinum rotate into a left-sided *pneumonectomy space more easily and with less increase* in volume of the contralateral lung.

Complications. (1) *Infection of the remaining lung.*—Some degree of bronchitis is extremely common, particularly in elderly subjects, and measures which should be taken to prevent the retention of secretion have already been mentioned. If the sputum is very sticky, 10 grains of ammonium chloride given in capsules two or three times a day will help to render it less viscid. Steam inhalations from water containing tinct. benzion. co. (1 drachm to the pint) may also aid in attaining the same object. If the patient is unable to keep the air-way clear by expectoration, bronchoscopy must be performed and the sputum removed by suction. This should be done under local anæsthesia (using a minimal amount of anæsthetic solution below the larynx) with the patient in his bed. Bronchoscopy may have to be repeated on several occasions but *it should never be performed until* the patient's own efforts, aided by further postural treatment, have proved ineffectual. The bacteriology of the sputum should be examined as a matter of urgency in case the organisms chiefly responsible for the

infection are penicillin-resistant, in which event the routine prophylactic course of penicillin may be reinforced or replaced by more appropriate chemotherapy.

(2) *Cardiac irregularities.*—Auricular fibrillation and flutter are common complications in the older age group, particularly in those cases where the vessels have been ligated within the pericardial sac. It is usual to treat fibrillation and flutter by some method of rapid digitilization so as to reduce the ventricular rate to a reasonable level. Subsequently, the patient is maintained on sufficient digitalis (usually about ½ grain of the folia every 8 hours) to keep the rate within normal limits. The course of digitalis can generally be discontinued after about 10 days as there is almost invariably a return to normal rhythm either during this period or shortly afterwards. Some clinicians prefer to use quinidine instead of digitalis and there is some evidence that gross cardiac irregularities occur less frequently if this drug is given in 5 grain doses every 6 hours for one day before operation and for 10 days afterwards.

(3) *Broncho-pleural fistula and empyema.*—Very occasionally the sutured bronchus does not heal completely but breaks down so that a communication is formed between the tracheo-bronchial tree and the pneumonectomy space. Fortunately the incidence of this serious complication has been greatly reduced during recent years. A broncho-pleural fistula most commonly arises about 10–14 days after operation but it may occur much later than this; sometimes there is an interval of several months or even years. It is exceptional for a large communication to develop suddenly but, should it do so, the patient may aspirate a large amount of pleural fluid into the opposite bronchial tree and thus drown in his own secretions. Therefore, those in immediate attendance should be warned of this possible catastrophe and instructed to turn the patient immediately on to the side of operation if a fistula develops. With fistulæ of such large size, it is essential to drain the pneumonectomy space forthwith and this should be done by rib resection under local anæsthesia with the patient in the sitting position. Rib resection is advised in preference to the insertion of an intercostal tube because the latter may fail to relieve the patient as the pneumonectomy space frequently contains much clot which may cause loculation of the fluid.

The development of a fistula is more commonly heralded by a rise of temperature which is followed by the expectoration of a little sputum stained with dark blood: there may also be some increased breathlessness due to a rise in pressure in the pneumonectomy space. These signs should be accepted as indications for immediate aspiration: as much fluid as possible should be withdrawn, a sample sent for bacteriological examination, and a million units of penicillin injected into the space. Sometimes by repeating this treatment and keeping the patient in the sitting position or lying on the side of operation a small fistula will heal and infection of the space be

prevented. If the fistula persists and continually reinfects the space, drainage becomes a necessity. If the fistula heals subsequently, it may be possible then to sterilize the space by the local application of suitable antibiotics and finally to remove the tube so that the ultimate result is similar to that of an uncomplicated pneumonectomy. If the fistula persists, the patient must either continue with a drainage tube *in situ* or submit to a thoracoplasty and any other accessory procedures necessary to obliterate the empyema cavity and close the fistula.

Very rarely infection of the space occurs in the absence of a fistula. Such cases should be treated by repeated aspiration and the injection of suitable antibiotics. If loculation by fibrin prevents sterilization of the space, the clot should be broken up by streptokinase (p. 324). The space should never be drained unless the infection persists in spite of the most determined efforts at sterilization by local chemotherapy.

(4) *Reactionary hæmorrhage.*—Severe bleeding into the pleural cavity following the return of the patient to the ward may be recognized by the escape of large quantities of blood from the drainage tube when the clamp is released. Such cases are now very rare. Treatment consists in immediate blood transfusion. If the hæmorrhage continues, it is necessary to take the patient back to the theatre, open up the wound and find and secure the source of the bleeding.

(5) *Secondary hæmorrhage.*—This can only occur in those cases complicate [illegible] then it is rare in spite of the fact that large [illegible] If severe but not immediately fatal, the [illegible] if the hæmorrhage continues, the wound must be reopened and the source either controlled by ligature or the whole cavity packed with dry gauze.

(6) *Wound infection.*—This is most uncommon. When it does occur and persists in spite of chemotherapy the infected part should be laid open and packed.

(7) *Suppurative pericarditis.*—This also is rare but the possibility of its occurrence should be borne in mind as the classical signs and symptoms may be absent. Treatment consists in aspiration and the intrapericardial injection of a suitable antibiotic. If the infection is not thus destroyed, the pericardial sac must be drained externally.

(8) *Brain abscess.*—Blood-borne infection to the brain is rare and is not necessarily fatal. The advice of a neuro-surgeon should be sought as soon as the condition is suspected.

(9) *Coronary thrombosis.*—This is sometimes responsible for the death of elderly patients. If the patient does not die at once, oxygen should be administered, morphine given and the use of anticoagulant therapy considered if the complication occurs after the first two post-operative weeks.

(10) *Pulmonary embolism.*—This is much less common after thoracic operations than after abdominal procedures. Nevertheless it is responsible for the death of a few patients following pneumonectomy,

particularly in cases of carcinoma. If not immediately lethal, the usual supportive measures should be provided. Subsequently it may be advisable to ligate one or both femoral veins.

Lobectomy

Indications for lobectomy.—The indications for lobectomy are in many ways similar to those for pneumonectomy (*see* p. 858) excepting that of course the disease must be more or less confined to the lobe to be resected.

(1) Bronchiectasis.—When complete bronchography of both sides has shown that the bronchial dilatation is limited to one lobe, removal of the affected lobe may be undertaken if the symptoms are sufficiently troublesome to warrant operation and if the patient's general condition is satisfactory. If the dilatation does not involve all the segments of the lobe it may be possible to conserve the healthy segments (*see* segmental resection, p. 881). In unilateral cases of bronchiectasis, it is common to find the lingular segment of the left upper lobe affected as well as the lower lobe, in which case the left lower lobectomy is combined with "lingulectomy". On the right side the middle and lower lobes are frequently both diseased and are then removed together. In bilateral cases, operation may be undertaken if it is possible to leave sufficient healthy lung for the patient's needs: for example bronchiectasis of the middle lobe is often associated with bronchial dilatation in the left lower lobe and lingula, in which case middle lobectomy may be undertaken and followed several months later by resection of the left-sided disease. If bilateral surgery is contemplated it is important to conserve any healthy segments whenever technically possible.

(2) Chronic lung abscess.—Lobectomy is being employed with increasing frequency for lung abscesses which have failed to respond to postural drainage and chemotherapy, that is, in preference to external drainage. Lobectomy is certainly indicated in chronic cases where there is already secondary bronchiectasis.

(3) Pulmonary tuberculosis.—The place of lobectomy in pulmonary tuberculosis is still the subject of much discussion. In brief, when the disease is largely confined to one lobe, lobectomy may be indicated under any one of the following circumstances:—

(*a*) When the lesion is entirely or largely solid.
(*b*) When the cavity is very large.
(*c*) When there is evidence that the cavity is of the "distension" type, that is, the bronchial communication with the cavity is persistently valvular.
(*d*) When there is gross stenosis of the lobar bronchus.
(*e*) When the disease is confined to the lower lobe.

Lobectomy should not be performed if the patient's disease is eminently suitable for thoracoplasty.

(4) **Innocent tumours.**—Innocent tumours unsuited to local removal either by bronchoscopy or bronchotomy (p. 360) should be removed by lobectomy whenever the anatomical position of the tumour allows.

(5) **Bronchogenic carcinoma.**—The operative treatment of malignant disease of the bronchus has been discussed on p. 360. In those patients who have a poor respiratory reserve lobectomy may be *undertaken in preference to pneumonectomy if the growth* is peripherally situated.

(6) **Hydatid cyst.**—Hydatid disease complicated by infection simulates a chronic lung abscess and requires treatment by lobectomy. An uncomplicated hydatid cyst may be treated by lobectomy if the cyst cannot be enucleated and the containing cavity either obliterated with sutures or removed by segmental resection (p. 384).

Pre-operative preparation is exactly similar to that described for pneumonectomy (p. 362).

Technique.—The chest is opened by a postero-lateral thoracotomy incision, the level of the opening depending on the lobe to be removed (p. 353). It is essential that the operator should be familiar with the anatomy of the main structures at the hilum of the lobe to be removed and *he must be prepared for variations in the pattern of the branches* of the pulmonary artery, especially of those supplying the upper lobes, particularly on the left side. If the anæsthetist is not in a position to prevent with certainty the spread of secretions into parts of the lung not to be removed it is highly desirable that the bronchus of the lobe to be resected is occluded at the earliest possible opportunity. In the case of the right upper and lower lobes and of the left lower lobe it is possible to isolate the lobar bronchus as soon as the chest has been opened, provided any adhesions which prevent access to the bronchus have been divided. A non-crushing clamp can then be placed across the bronchus so that no further secretions can be expressed from the diseased lobe. In the case *of the left upper lobe*, access to the bronchus cannot be gained until the branches of the pulmonary artery leading to the lobe have been ligated and divided. It is also difficult to clamp the middle lobe bronchus before division of the middle lobe artery. In the author's opinion, provided the anæsthetist has control of the secretions, it is safer and technically easier to divide at least some of the branches of the pulmonary artery before placing a clamp across the lobar bronchus in *all* cases, and the main operative steps necessary for the removal of each individual lobe will be described on this understanding

Right upper lobectomy. (Fig. 135).—Any adhesions over the lobe are either divided or separated from the chest wall in the extrapleural plane The lobe is then retracted backwards and the pleura divided on the anterior aspect of the hilum of the lung. The cellular tissue overlying the pulmonary artery is separated and the main upper lobe branch isolated in the subadventitial plane· this branch is ligated with strong

thread close to its origin, clamped distally and divided. The peripheral end is then ligated and the clamp removed. The lobe is subsequently retracted downwards and forwards and the mediastinal pleura divided as it passes on to the superior and posterior aspects of the lobar bronchus. The bronchial vessels passing on to the posterior aspect of the bronchus are divided between ligatures. A long curved clamp is then insinuated in the angle between the inferior border of the lobar bronchus and the lateral wall of the continuation of the main bronchus. A lymphatic gland which invariably occupies the angle formed by these

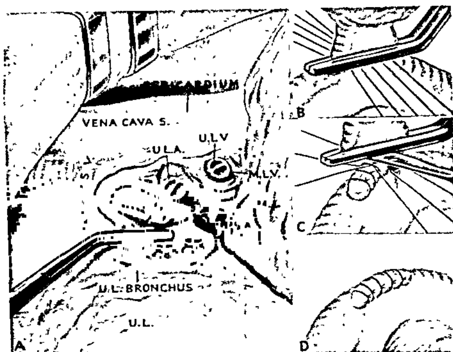


Fig. 135.—Right upper lobectomy.

[illegible]

U L.A. = Main upper lobe branch of the pulmonary artery.
P S A = Pulmonary arterial branch passing to the posterior segment.
U.L V. = Upper lobe vein.
M L.V. = Middle lobe vein
M L. = Middle lobe
U L = Upper lobe

two bronchi is thus separated from the upper lobe bronchus. After completing the isolation of the bronchus in the plane immediately against the bronchial wall a clamp is placed across the bronchus about 1 cm. from its origin. Interrupted stainless steel sutures on eyeless needles are then passed at intervals of about $\frac{1}{3}$ cm. from before backwards through both walls of the bronchus which is divided just proximal to the clamp, the sutures being tied as the division proceeds. The lobe is again retracted backwards and the superior pulmonary vein is isolated *lateral* to the point at which it receives the middle lobe vein; after making sure that the middle lobe vein has not been included,

the upper lobe vein is ligated proximally, clamped distally and divided. By gentle blunt dissection the cellular and glandular tissues are separated from the main descending branch of the pulmonary artery until the arterial branch passing to the posterior segment of the upper lobe is displayed. This branch, which varies much in size, is ligated and divided. By traction on the clamp applied to the distal end of the bronchus the plane of separation between the upper lobe

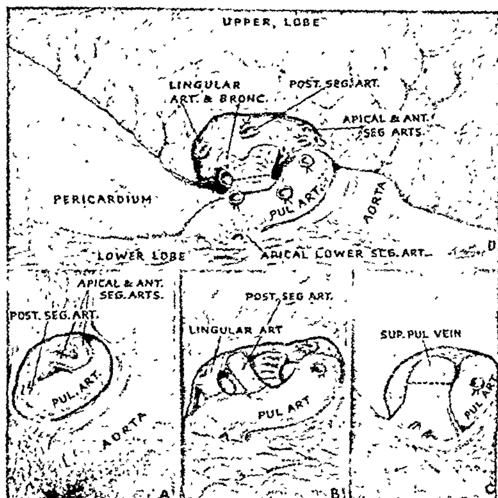


Fig. 136.—Left upper lobectomy.

A, The pleura over the upper aspect of the hilum has been incised so as to expose the pulmonary artery and its apical, anterior and posterior segmental branches. B, The apical and anterior segmental arteries have been divided and the dissection continued along the interlobar *fissure so as to expose the lingular artery.* (The upper lobe is retracted forwards and the lower lobe backwards.) C, The upper lobe is now retracted backwards so as to expose the superior pulmonary vein. D, The upper lobe is again retracted forwards and the bronchus exposed from behind.

and the adjacent lung tissue can be identified even if the interlobar fissures are incomplete or absent: if firm pressure with a gauze swab is made in this plane the lobe can be entirely freed and removed. After completing hæmostasis, the phrenic nerve is crushed, an apical "sucker" and a basal drain are inserted and the chest is closed.

Left upper lobectomy. *(Fig. 136).—It is necessary to start by isolating* and dividing the branches of the pulmonary artery which pass from

the antero-lateral border of the main artery to the upper lobe. These branches vary from two to six in number, the lowest being that which passes downwards and forwards to the lingular segment. Subsequently it is usually easiest to isolate and divide the superior pulmonary vein so that the lobe remains attached solely by the bronchus which can then be clamped, divided and sutured as previously described. The operation is completed as described for right upper lobectomy.

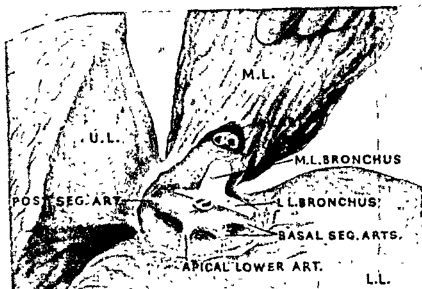


Fig. 137.—Right middle lobectomy.
The middle lobe artery has been divided between ligatures and the middle lobe bronchus is exposed.
U.L. = Upper lobe
M.L. = Middle lobe
L.L. = Lower lobe.

Right middle lobectomy. (Fig. 137).—The main descending branch of the pulmonary artery is exposed by division of the pleura at the bottom of that part of the oblique fissure which joins the transverse fissure. The fissure is usually incomplete and has to be developed by blunt dissection. The middle lobe artery which passes forwards from the anterior border of the main descending branch is isolated and divided. By gentle backward retraction of the main descending artery the middle lobe bronchus may be seen lying below and medial to the original position of the middle lobe artery. It is isolated and clamped about 1 cm. from its origin. Any adhesions over the anterior and mediastinal surface of the lobe may now be divided. By retracting the lobe backwards and laterally the middle lobe vein can be seen entering the superior pulmonary vein: it is isolated and divided. Attention is again turned to the bronchus which is divided proximal to the clamp and the stump sutured. By applying traction to the clamp on the peripheral end of the middle lobe bronchus the lobe may be freed from the upper and lower lobes as described under right upper lobectomy. The phrenic nerve is *not* crushed. A basal drain is inserted and also an apical " sucker " if the apex of the upper lobe is not adherent.

Left lower lobectomy. (Fig. 138).—The main descending branch of the pulmonary artery is found at the bottom of the upper part of the oblique fissure. It is necessary to expose the branches passing to the lingular segment of the upper lobe and to the apical segment of the lower lobe as it is not uncommon for the lingular branch to leave the main descending artery below the branch to the apical segment of the lower lobe. Under such circumstances the descending artery

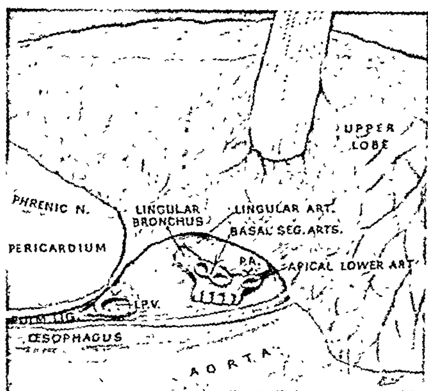


Fig. 138.—Left lower lobectomy.

Diagram showing the anatomy after removal of the left lower lobe. The sutured bronchus is seen posterior to the divided arteries.
I.P.V. = Inferior pulmonary vein.

must be ligated and divided below the lingular artery and the branch to the apical segment of the lower lobe ligated and divided separately. The lower lobe bronchus can now be isolated and clamped *close to the* origin of the upper lobe bronchus. It is usually easiest if the bronchus is now divided and sutured. Subsequently the pulmonary ligament is divided between clamps and the inferior pulmonary vein isolated, ligated and divided and the lobe removed. The phrenic nerve is not crushed. An apical " sucker " and basal drain are inserted under the same conditions as for middle lobectomy.

Right lower lobectomy. (Fig. 139).—The technique for right lower lobectomy differs from that employed on the left side in the following ways:—

(1) The middle lobe artery takes the place of the lingular branch and requires careful preservation

(2) The middle lobe bronchus frequently takes origin at the same level as the bronchus to the apical segment of the lower lobe. Division and suture of the lower lobe bronchus must then be oblique so that there is no interference with a free airway to the middle lobe.

Right middle and lower lobectomy.—In this case the pulmonary artery is exposed in the oblique fissure immediately above the middle lobe branch; in freeing it prior to ligation care must be taken to avoid damage to the branch passing to the posterior segment of the upper lobe as this branch frequently takes origin close to the intended site of

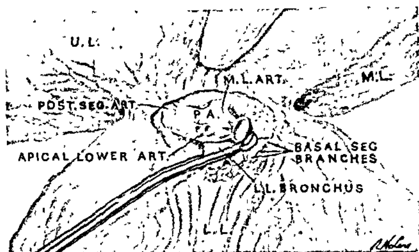


Fig. 139.—Right lower lobectomy.

The branches of the pulmonary artery passing to the lower lobe have been divided and the bronchus is clamped.

U L = Upper lobe M L = Middle lobe L L = Lower lobe

ligation of the main artery. The continuation of the main bronchus below the upper lobe branch can now be freed preparatory to its division. The resection is completed by isolation, ligation and division of the inferior pulmonary vein and the middle lobe tributary of the superior vein. The rest of the operation is similar to that described for a lower lobectomy

If an opening into the pericardial sac is accidentally made during any form of lung resection it is advisable not to attempt closure of the hole by suture

The original method of lobectomy employed a tourniquet to provide temporary mass ligation of the hilar structures of the lobe to be resected; these structures were then occluded by continuous suture (*see* Modern Operative Surgery, 3rd Ed , Vol. I, p. 333), but this method is rarely used now as it has been almost completely replaced by the individual ligation or suture of the main structures as described above.

The post-operative care and complications are in many ways similar to those described for pneumonectomy (q v), the essential difference being that there is at least one lobe remaining which must at all costs be made

to expand and fill the hemithorax. This involves a different type of management of the tube drainage of the pleural space and also of postural treatment to prevent retention of bronchial secretions.

For an upper lobectomy the patient is nursed lying on his back with the foot of the bed raised so that gravity may help to displace the lower lobe towards the upper part of the thorax. This position is used also, but to a less extent, following lower lobectomy as it is of paramount importance that the apex of the upper lobe should be kept in contact with the cervical cupola. To encourage expansion of the lung so as to obliterate the apical part of the pleural space, the apical tube is connected to constant suction of about — 5 cm. of mercury; if there is a continuous air-leak from the lung, a pump having a large volume capacity should be used in order to evacuate the air from the pleural space faster than it can escape from the lung. If such a pump is not available, it is advisable to connect the apical tube to a water-seal drain until the leak of air from the lung has diminished: suction may then be given a further trial. The basal tube is connected to a water-seal drain and continuous drainage (cf. pneumonectomy) provided. If the upper lobe expands to fill the hemithorax after a lower lobectomy and if the amount of drainage is small (less than 300 ml. of drainage in 24 hours) both tubes are removed after 48 hours. In the case of upper lobectomies it is often advisable to leave the apical tube in for another 24 hours. If fluid collects in the pleural space subsequent to removal of the tube, this must be removed by aspiration.

Breathing exercises and expectoration of sputum after lobectomy are even more important than after pneumonectomy for it is essential to keep a free air-way if the remaining lobe is to fill the hemithorax. Postural treatment should be directed mainly at keeping the air-ways clear on the side of operation and the patient should therefore be rolled on to the "*good*" side for periods of ½–1 hour several times during the 24 hours. If the remaining lobe collapses, efforts to clear the air-way by expectoration must be redoubled and if these efforts fail to produce expansion of the collapsed lobe after 8–12 hours the secretions must be aspirated through a bronchoscope passed under local anæsthesia with the patient in his bed (children require general anæsthesia). The need for restoring re-aeration of the collapsed lobe is very urgent for if expansion is delayed for more than 2–3 weeks there is almost inevitably permanent damage in the form of bronchiectasis, which was not present before operation and it may even be necessary to perform a second operation for the removal of the newly-diseased area. Unlike pneumonectomy the question of thoracoplasty does not arise unless there is a persistent air-space or localized empyema at the apex.

Pleural infection is rare but, when it occurs, should be treated by aspiration and local chemotherapy; if this fails to eradicate the infection and a localized empyema develops, drainage by rib resection is required.

Exceptionally a bronchial fistula occurs: in this case any residual pleural fluid must be aspirated completely and the pleural space

subsequently kept dry by repeated aspiration. If this is done the bronchial fistula will sometimes heal but, if it fails to do so, the pleural pocket with which it communicates must be drained and managed as any other empyema (p. 333).

Late development of tuberculosis.—It has been found that about 2 per cent. of cases of lobectomy for bronchiectasis develop tuberculosis in the remaining lobe. No definite reason for this has been discovered.

Segmental Resection

Indications.—(1) *Bronchiectasis which does not involve a whole lobe.* The most frequent example of this is disease in the lingular segment of the left upper lobe, usually associated with disease in the lower lobe. Another important example is disease confined to the basal segments of a lower lobe, the apical segment being normal. This may be an indication to remove only the basal segments but the operation is technically more difficult and the incidence of complications slightly higher than after a simple lower lobectomy; therefore it is doubtful whether basal segmental resection should be preferred to simple lobectomy if there is no disease in any other lobe. However, if there is bilateral disease, conservation of a healthy apical segment may considerably help the patient's post-operative respiratory function.

(2) *Pulmonary tuberculosis.*—Tuberculous lesions which have been shown by lateral tomography to be limited to one or two segments of a lobe may sometimes be removed by segmental resection, provided the limited nature of the disease is confirmed at operation. This particularly applies to solid lesions and to lesions of the apical segment of the lower lobe. It is common to find cases of pulmonary tuberculosis in which the disease is confined to the apical and posterior segments of the upper lobe. When this occurs on the left side it is possible to conserve the pectoral and lingular segments which embody a large mass of healthy lung tissue but it is much more doubtful whether conservation of the pectoral segment on the right side is worth while.

(3) *Hydatid disease.*—After enucleation of the worm cyst (p. 387) there remains a cavity in the lung from which the cyst was removed. There are usually one or more bronchial fistulæ communicating with the cavity. These fistulæ commonly communicate with the bronchi of only one pulmonary segment. If this segment is anatomically well situated for resection it is probably preferable to remove it rather than attempt obliteration of the fistulæ and of the cavity by suture.

Technique.—The principles on which segmental resection are based are applicable to any segment whatever its anatomical position. It is first necessary to expose the hilum of the lobe of which the segment forms part The one or more branches of the pulmonary artery leading to the segment to be resected are carefully dissected out and divided between ligatures. The segmental bronchus is then usually visible and can be isolated by blunt dissection, clamped, divided and the proximal stump sutured. With moderately strong retraction of the

peripheral end of the bronchus it is often possible to display one or more tributaries of the pulmonary vein which lead from the affected segment: these are also divided between ligatures. By continuing traction on the bronchus the affected segment will start to separate from the adjacent segments. This separation is aided by firm pressure with a piece of gauze along the intersegmental plane, working steadily and centrifugally from the lobar hilum. This process ruptures small venous tributaries passing from the segment to the intersegmental vein. If there is difficulty in following the intersegmental plane the

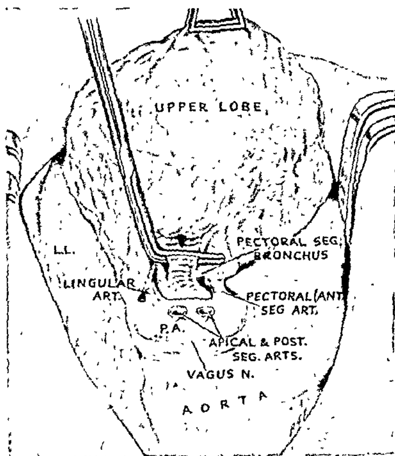


Fig. 140.—Resection of the apical and posterior segments of the left upper lobe.
The segmental arteries have been divided and a clamp has been placed across the apico-posterior bronchus
L.L = Lower lobe

anæsthetist can help by applying positive pressure which will rapidly inflate the segments of the lobe which are not undergoing resection, whereas the tissue to be excised will only fill with air very slowly as the air can only enter the segment through alveolar communication with adjacent segments. Finally the segment is left attached solely by the visceral pleura and this is cut with scissors

There is always some bleeding from the ruptured tributaries of the intersegmental vein but this usually ceases spontaneously if the space from which the segment has been removed is packed temporarily with

dry gauze. When the resection has been completed the anæsthetist applies positive pressure to inflate the remaining lung tissue and this commonly leads to some leak of air from the exposed alveoli. If there is much leak of air it is probable that the resection has not been carried out strictly in the intersegmental plane and the surgeon must search for any small torn bronchi which require ligation. If the correct plane has been followed the intersegmental vein and its tributaries will be seen " like a grape-vine on a wall " (quoted from R. C. Brock).

Brief reference will now be made to the technique employed in removing the segments most commonly submitted to resection.

Apical and posterior segments of the left upper lobe.—The pleura is divided over the pulmonary artery as it enters the lung and the superior surface of the vessel cleared until the branches passing to the upper lobe (other than the lingular branch) are exposed. Most commonly the first branch passes to the pectoral segment and this must be preserved but it may give a subsidiary branch to the apical segment and this will then require division. The second branch invariably passes to the apico-posterior segments and must be divided. (Very rarely the pulmonary arterial flow to the whole upper lobe excluding the lingula arises as one branch.) The posterior aspect of the upper lobe bronchus distal to the origin of the lingular branch is now exposed. This must be dissected peripherally so as to show the division of the apico-pectoral bronchus into pectoral and apico-posterior divisions: because the pectoral branch passes forwards from the anterior aspect of the apico-pectoral bronchus it may be difficult to display, but a clamp must not be placed across what is supposed to be the apico-posterior bronchus until the operator is satisfied that the pectoral branch has been spared (Fig. 140). After placing the clamp, the bronchus is divided proximally and the stump sutured. By applying traction to the clamp it is usually obvious whether there are any further branches of the pulmonary artery which pass to the segments undergoing resection and which therefore require division. Venous tributaries are exposed by continuing the traction and divided accordingly. When the apico-posterior segments have been stripped out from the rest of the upper [illegible] s when inflated [illegible] for its respira- [illegible] but also in helping to fill the hemithorax.

Apical, posterior and pectoral segments of the left upper lobe.—The operation [illegible] bronchus is sectioned proximal to the origin of the pectoral branch. Also, as all the tributaries of the superior vein excepting the lingular veins require division, it is preferable if the vein is ligated as a whole distal to the point at which the lingular veins enter it rather than ligating the tributaries as they are exposed.

This operation leaves only the lingular segment of the upper lobe

behind but this is most valuable in helping to fill the upper and anterior part of the chest.

Lingular segment of the left upper lobe.—If resection of the lingula is combined with removal of the left lower lobe the lobectomy should be completed first. It is then easy to dissect out the lingular artery which passes downwards and forwards and divide it. The lingular bronchus is now exposed and must be isolated, clamped, divided and sutured. If the lingular bronchus divides early into superior and inferior divisions it is easy to mistake the inferior division for the main lingular bronchus and care must therefore be taken to isolate and divide the bronchus close to its origin from the lobar bronchus. If the clamp on the peripheral end of the bronchus is lifted away from the mediastinum, the lingular vein which lies a little antero-medially can be exposed, dissected free, ligated and divided. The segment is then stripped from the rest of the upper lobe in the usual way.

Apical segment of the right or left lower lobe.—The main descending branch of the pulmonary artery is exposed as for a lower lobectomy. The branch to the apical segment which passes almost directly backwards can then be isolated and divided. By gentle forward traction of the main descending branch of the pulmonary artery the origin of the bronchus passing to the apical segment can be seen arising from the posterior wall of the lobar bronchus. It is divided close to its origin. If the whole lower lobe including the apical segment is now retracted forwards the vein passing from the apical segment to the inferior pulmonary vein can be dissected free and divided. The apical segment is now ready for separation from the rest of the lower lobe by the usual centrifugal blunt dissection.

Basal segments of the right or left lower lobe.—The technique is the same as for a lower lobectomy (q.v.) except that the artery and the bronchus are divided distal to the origin of their branches passing to the apical segment. Care must also be taken to preserve the vein draining the apical segment. In some cases, after stripping the basal segments from the apical segment, it is pleasantly surprising to find that the apical segment is a much more voluminous portion of lung than is often anticipated

Post-operative care and complications.—These are exactly similar to those associated with lobectomy except that the leak of air from the "raw" lung surface is usually greater than that after lobectomy. Also the patient must be warned to expect quite heavy blood-staining of the sputum during the early post-operative days as there is bound to be some contusion of the segments adjacent to that removed.

Removal of Hydatid Cysts

A most authoritative study on the treatment of pulmonary hydatid disease has been published by N R. Barrett and Dillwyn Thomas* and their views are freely quoted in this section.

* Brit. J Surg, 1952, xl, 222.

Simple hydatid cysts should be removed from the lung as soon as they are diagnosed, for spontaneous cure as a result of rupture of the worm cyst and expectoration of the contents and all fragments of the hyaline wall are exceptional. Unless the cyst is small, delay in treatment exposes the patient to the risks of anaphylaxis, infection of the cyst, intrapleural rupture and other less common complications.

Barrett and Thomas emphasize the pathological points which are of importance to the surgeon:—

(1) If hydatid fluid is allowed to contaminate an operation wound in the lung or chest wall or if it reaches the pleural cavity, anaphylaxis or new hydatids may develop.

(2) The *young* parasite causes no permanent changes in the surrounding lung. It is only around really large, or long-standing, cysts that the capsule of the host (" the adventitia ") is formed of fibrous tissue and even then the capsule is only a few millimetres thick and is sharply demarcated from the normal surrounding lung unless secondary infection has occurred. A simple cyst compresses the surrounding lung tissue but rarely produces any permanent damage to it.

(3) The intact hyaline membrane is strong and can often withstand the alterations in shape when a hydatid herniates out of the lung, but as soon as it has been perforated by a needle or grasped with forceps it tears.

(4) A simple cyst is usually associated with a free pleural cavity and only filmy bands develop over the exposed adventitia.

In the past, simple hydatid cysts were frequently treated in a manner similar to that employed for the external drainage of a lung abscess (q.v.), that is, the cyst was accurately localized and a portion of rib over the cyst excised; adhesions between the two layers of pleura in the vicinity of the cyst were usually found to be absent unless an artificial pleurodesis (p. 320) had been performed previously and even then the chemically-induced pleurisy frequently failed to form adhesions over the cyst: in such circumstances a gauze pack, which was sometimes previously soaked in tincture of iodine, was placed against the parietal pleura and left *in situ* for ten days; the pack was then removed, the wound was covered with gauze soaked in 1 per cent. formalin, the adventitia was opened and the worm cyst was evacuated using suction so as to avoid too much contamination of the wound. The cavity was subsequently packed open until healing had occurred. This method of treatment has the following disadvantages:—(1) It is not applicable to cysts which are not in contact with the chest wall, (2) prevention of pleural contamination depends on having firm adhesions over the cyst and such adhesions are difficult to produce, (3) there is inevitably some contamination of the wound and lung cavity with the contents of the cyst, and (4) the cavity is certain to become more or less infected due to the external drainage.

Therefore, for simple cysts, this operation should be given up and replaced by removal of the cyst intact after opening the chest widely by a suitably-placed thoracotomy incision. This operation aims at

removal of the parasite without contaminating the wound or pleural cavity with live hydatid elements and also subsequently allows measures to be taken to obliterate the " empty sac " which remains in the lung.

The method to be described has no place in the management of cysts complicated by infection, by the formation of daughter cysts or by secondary bronchiectasis, the last being rare if the cyst itself is uninfected.

Pre-operative investigation should include careful radiological examination in order to ascertain the exact position of the cyst· on occasion more than one cyst is present but the number never exceeded three in Barrett and Thomas's series of 71 cases. With multiple cysts, each one requires localization. Bilateral cysts are no contraindication to their removal but an interval of several months should be allowed between the two operations. In cases where there is uncertainty as to whether the cyst is in the lung or in the liver, a distinction can usually be made by inducing an artificial pneumoperitoneum If the diagnosis is in doubt there is no place for diagnostic aspiration as this manœuvre not only may rupture the cyst and disseminate the disease, but the patient may react to aspiration by anaphylactic shock. In exceptional cases where there are symptoms or signs suggesting secondary bronchiectasis bronchography should be carried out because, if bronchial dilatation is confirmed, this should be accepted as an indication for resection of the diseased lobe or segments together with the cyst. Cysts complicated by the presence of daughter cysts should also be treated by resection.

The operation (after Barrett and Thomas).—" The patient is given a general anæsthetic, and this is maintained after a cuff tube has been introduced into the trachea to make an air-tight circuit. The head of the table is lowered so that if the cyst ruptures into the bronchus the liquid drains from the lungs by gravity The appropriate hemithorax is opened either by rib resection or an intercostal incision placed at about the level of the middle of the cyst, and the pleural cavity is opened *widely* with rib spreaders (*see* Major Thoracotomy, p. 353). The affected lobe, or, where a giant cyst is present, the cyst, is then enclosed in a bag of mackintosh, made like a sponge bag, with strings at the top for gathering up the inlet, but the bottom is cut open. The bag is placed round the lobe containing the cyst with the strings at the hilum, and these are drawn up to encircle the neck of the lobe without impeding respiration in the lobe or the blood-supply. The bottom of the bag is then opened out, brought through the incision and spread out on the surface of the wound. The exact position of the cyst in the lobe is now ascertained and in most cases the adventitia will be seen on the surface of the lung as a patch of white membrane. If the hydatid has not grown up to the surface, the lung is incised along one of the intersegmental planes over the cyst and down to the adventitia. The stage is now set for removing the cyst." Formerly it was at this moment that aspiration of the cyst with a fine needle

was recommended so that the cyst separated from the adventitia but this inevitably led to some contamination of the lung with hydatid fluid and, unless the cyst is as large or larger than the size of a grape-fruit (for the treatment of which see later), the operation is continued as follows:—" The *adventitia is partially incised by a straight cut* with a knife. The length of the incision should be about the same as the diameter of the cyst measured in the radiographs, and it should be placed towards the bottom of the cyst as the patient lies on the table. The incision must be made cautiously, because as a rule the adventitia is not more than ⅛ in. thick. The object is to form a crack in the adventitia and not to expose the laminated membrane throughout the length of the incision. Once the laminated membrane has been exposed in one spot the incision in the adventitia can be extended by lifting it off the cyst and cutting the lung in several directions with blunt-pointed scissors. If the method has been used correctly the cyst begins to herniate out of the lung.

The surgeon's job is now for the time being over; success depends on not touching the parts until the cyst has been extruded from the lung. In particular neither the laminated membrane nor the adventitia should be touched or grasped with toothed forceps. Extrusion is achieved by the anæsthetist who steadily increases the pressure in the anæsthetic circuit so that little by little the hydatid is extruded from the lung intact, and lies in the mackintosh bag. During this period there must be no attempt to hurry matters, and if the surgeon cannot be persuaded to leave well alone the safest instrument for him to use is a sterile household spoon of appropriate size.

The operation table should now be tilted towards the surgeon so that by tightening the lower margin of the bag and by gently introducing the hand behind the extruded parasite, it can be lifted from below so that it rolls naturally into a porringer held to receive it." Before enucleation is started a powerful sucker should be ready in case the cyst is opened accidentally.

After enucleation of a hydatid one or more bronchial fistulæ can generally be seen opening upon the walls of the space from which the cyst has been enucleated: these should be closed by ligature or suture. The "sac" is then obliterated by a series of purse-string sutures inserted seriatim from the bottom to the surface of the space. The thoracotomy wound is then closed after the insertion of an apical sucker and a basal drain as described for lobectomy.

Cysts the size of a *grape-fruit or larger should not be treated* by this method as they are very liable to rupture and further, the adventitia is formed of fibrous tissue which tends to hinder obliteration of the "sac". They should be dissected out together with the adventitia there is then usually an opening at the bottom of the cavity in the main bronchus of the segment in which the cyst developed; this opening must be carefully sutured and the cavity subsequently obliterated by a series of purse-string sutures.

Infected cysts most frequently require removal by lobectomy or

resection of the one or more affected segments. If the infection is relatively recent and has not caused gross inflammatory change in the lung adjacent to the cyst the cavity may be treated by one-stage drainage of the abscess if pleural adhesions are present: the hydatid elements, which must all be removed, are probably dead but it is wise to avoid contamination of the wound as far as possible. If adhesions are few or absent the opening in the chest may be enlarged, and the abscess opened "across the pleural cavity": the débris is then removed and the cavity sewn up after lining it with antibiotic powders.

Removal of Localized Lesions by Enucleation or Wedge-resection

On occasion localized lesions in the lung, for example solitary cysts or peripherally-situated innocent tumours, may be removed by incising the lung over or at the margins of the lesion and enucleating it with its capsule by stripping the lung from the external surface using a combination of scissor- and blunt-dissection. If there is not much bleeding or air-leak from the denuded surface of lung the thoracotomy wound is closed after providing adequate pleural drainage. Hæmorrhage should be controlled by ligation of the obviously bleeding vessels and subsequently oversewing the raw surface of lung. The latter is also usually the best method of controlling leak of air from the torn alveoli and small bronchi.

Sometimes it is preferable to remove the lesion together with the immediately adjacent lung tissue, particularly if the lesion is situated near the free border of a lobe. In this case non-crushing clamps such as Crafoord's coarctation clamp or Brock's auricular clamp are placed across the lung tissue just proximal to the part to be excised and the lung is divided with scissors leaving a small fringe distal to the clamps this fringe is sealed with a continuous suture of cat-gut before removing the clamps.

These very limited operations are useful in removing small lesions which have been picked up on mass radiography and which appear at subsequent thoracotomy to be of an innocent nature.

Surgical Treatment of Penetrating Injuries of the Lung and Pleura

The treatment of penetrating wounds of the chest depends more on good judgment than on special operative technique. The measures that may be required may be considered according to the period which has lapsed since the injury.

(1) Emergency treatment.—In the great majority of cases there is considerable shock and this may be further aggravated by hæmorrhage: resuscitation of the circulation by blood transfusion, etc, is therefore generally required as a matter of urgency. Obvious bleeding from the chest wall may be controlled by ligature without anæsthesia. A wound in the chest wall which permits air to flow back and forth from the pleural cavity on respiration is referred to as a "sucking wound": this air leak

causes serious embarrassment to respiration and must be controlled at the earliest possible moment; this can usually be achieved by placing a gauze pad over the wound and strapping this firmly in place but, in exceptional cases, it may be necessary to draw the tissues over the hole in the thoracic cage by the use of stitches passed through the skin and superficial muscles; as the wound has not been excised these stitches must always be removed later when the patient has been resuscitated.

Rarely the wound in the lung causes a tension pneumothorax which calls for urgent relief (*see* p. 319).

(2) Early operation after resuscitation.—Operative treatment should very rarely be undertaken until the effects of shock and hæmorrhage have been successfully treated; exceptionally, for example when there is continued hæmorrhage or when there is evidence of abdominal visceral damage associated with a thoraco-abdominal wound, operation may be so urgent that it is justifiable to proceed before the blood pressure has been fully restored to normal, but the danger of operating under these circumstances should be carefully weighed against the dangers of further delay. Even when the blood pressure has reached normal levels, the surgeon should understand that the circulation in patients with severe chest injuries is unstable so that serious shock may return if extensive and prolonged surgery is carried out. When X-ray facilities are available, operation should not be performed until satisfactory anterior and lateral films of the chest have been obtained; increased penetration should be used as the injured side of the chest is likely to be relatively radio-opaque. If X-ray facilities are not available, operation should not be carried out unless the indications for surgery are most pressing

When the indications are present, early operative treatment should be performed within 12 hours of the patient receiving the wound: on occasion a delay of up to 24 hours may have to be accepted but, if more than 24 hours have passed, it is probably preferable to treat the patient initially by conservative measures and reserve surgery for the treatment of complications. The importance of early surgery has been greatly stressed in the past because of its capacity to reduce the incidence of septic complications, but chemotherapy, both systemic and local when applicable, has reduced the frequency and seriousness of infection, so that the prevention of sepsis is now a less important indication for early operation.

Early operation may be performed for one or more of the following purposes:

(1) To excise the wound and repair the chest wall.
(2) To control continued hæmorrhage.
(3) To remove bone fragments which have been driven into the lung or foreign bodies which have been retained in the lung, pleural cavity or chest wall.
(4) In the case of thoraco-abdominal wounds, to explore the abdomen through the diaphragm in order to repair any damaged viscera in the abdomen.

Wound excision and repair of chest wall.—When the pleural cavity has been penetrated th ...
the superficial
...ough it be very
... atmosphere and
... pleural cavity; the anæsthetist must therefore be in a position to

[illegible] rgeon should aim to remove all damaged [illegible] and to control hæmorrhage from the [illegible] thoracic cage should be repaired as far as possible by suture of the intercostal tissues and periosteum: if the deficiency cannot be closed completely the residual opening may be ignored if it is situated posterio[illegible] particularly if it lies [illegible] thick outer covering. [illegible] either with a prosthesis such as tantalum gauze or, if no suitable material is available, with a pedicled graft of muscle, for example a portion of pectoral muscle. The superficial tissues are then sutured loosely after the application of penicillin powder. Before the wound is rendered hermetic the anæsthetist should make sure that the lung is fully inflated so that there is no residual air in the pleural space. If the defect in the chest wall was considerable it is wise to drain the pleural space for 2 to 3 days with an intercostal catheter so that the lung may continue fully inflated and thus adhere to the margins of the wound

The control of continued hæmorrhage.—External hæmorrhage from the chest wall wound obviously calls for exploration and control of the bleeding. On rare occasions there is evidence of continued intrapleural hæmorrhage; this almost certainly arises from the chest wall as bleeding from the pulmonary circuit nearly always ceases spontaneously; continued internal hæmorrhage is therefore an indication for early exploration of the chest wall wound.

The removal of bone fragments or retained foreign bodies.—Shell fragments more than 1 cm. in diameter are liable to carry portions of clothing into the chest and therefore may give rise to septic complications; further, large fragments are prone to cause late complications such as hæmoptysis; consequently they should be removed by early operation whenever practicable. This also applies to bone fragments which have been carried into the lung or pleural cavity from the chest wall. Smaller shell fragments are not likely to cause complications and may therefore be ignored. Bullets are less prone to introduce sepsis and operation for their removal can usually be postponed without risk until the patient is convalescent from the effects of the injury. On the other hand, animal or vegetable fragments such as pieces of wood or clothing almost inevitably lead to sepsis and should be removed at the earliest opportunity.

When an operation is performed in order to remove retained foreign bodies, the opening in the chest should be made in a position likely to give easy access to the foreign body and should be large enough to permit repair of the damaged lung when required and to clear out all blood clot from the pleural cavity. The opening in the chest is made in a manner similar to that described under thoracotomy (p. 353), although the purposes of the operation can usually be fulfilled with an incision which is less extensive than that required for, say, lobectomy. The site of thoracotomy is dictated by the position of the foreign material and should not be influenced by the situation of the entry wound: on occasion the entry wound may be included in the thoracotomy incision and must then be carefully incised. Bloody fluid, clot and any foreign material in the pleural cavity are removed. A foreign body in the lung can usually be located with ease either by palpation or by following the track along which it has passed, as this is surrounded by a zone of hæmorrhage into the lung In many cases

the foreign material can be removed with sponge-holding or foreign body forceps passed along the track but, if the track is very long, it may be more satisfactory to incise the lung immediately over the foreign body. The track and cavity from which the foreign body has been removed are insufflated with penicillin powder. Any torn or incised lung is then repaired with cat-gut stitches. The surgeon should appreciate the remarkable capacity of the lung to recover from injury and should only proceed to resect a lobe if the damage is exceptionally severe, for major surgery such as lobectomy is tolerated poorly by a recently wounded patient.

The thoracotomy wound is then closed after placing an apical " sucker " and a basal drain as described under lobectomy: these tubes can be removed after two to four days if the lung has expanded satisfactorily.

Exploration of the abdomen in thoraco-abdominal wounds.—In thoraco-abdominal wounds, unless there is reason to suspect visceral damage in the lower half of the abdomen, exploration of the abdomen is preferably carried out through the diaphragm. Nearly all wounds on the left side require exploration as these are likely to be associated with injury to the spleen or hollow viscera. On the right side, if the injury appears to be limited to the liver and if there is no evidence of continued hæmorrhage, the patient may be treated conservatively unless the fragment is sufficiently large to require removal in order to prevent sepsis, etc. In most cases the best exposure is obtained by opening the chest through the eighth intercostal space using a postero-lateral incision. After the fluid and clot have been removed from the pleural cavity and the lung has been repaired when necessary, the wound in the diaphragm is excised and the incision in it extended so as to provide adequate exposure of the damaged organs in the abdomen. If the diaphragm is opened widely it is possible to carry out almost any upper abdominal operation such as splenectomy, or suture of the stomach, colon or small intestine. If hollow viscera have been damaged it is important to place large packs so as to avoid contamination of the pleural cavity. The diaphragm is then closed with interrupted everting mattress sutures of thread followed by a continuous cat-gut suture along the cut border.

If peritoneal contamination has occurred, drainage of the affected area should be provided with a tube which is brought out through a suitably placed " stab " incision in the abdominal wall.

The chest is closed in the usual way after inflating the lung and providing adequate pleural drainage.

(3) Delayed operative treatment.—With the exception of operation to remove foreign bodies or bone fragments, the operative treatment of penetrating wounds delayed beyond the first week consists in that required for clotted hæmothorax (p. 324) and for septic complications such as empyema (p. 328) and, rarely, lung abscess (p. 347).

When a patient has made a satisfactory convalescence from the effects of a penetrating chest wound it may be necessary to consider the advisability of removing a metallic foreign body embedded in the lung. By and large it is proper to remove pieces of metal which are larger than 1 cm. in diameter, particularly if they are jagged, whether they are giving rise to symptoms or not: smaller fragments may be ignored unless giving rise to definite symptoms.

In all cases the anatomical position of the foreign body should be accurately localized by radiology. If it is close to the surface and is in a portion

of the lung which can be easily exposed, for example anteriorly or in the axilla or in the lower half of the chest posteriorly, it may be possible to remove the fragment by a very limited thoracotomy similar to that used for drainage of an empyema, *provided* the fragment has been localised with absolute accuracy. In other situations or if deeply placed in the lung, the chest must be opened by a more extensive thoracotomy incision. The foreign body is located by palpation and the lung over it incised keeping as far as possible to the intersegmental planes. After it has been removed the lung is repaired with cat-gut sutures. If the pleural cavity has not been obliterated with adhesions it is advisable to insert an intercostal drain before closing the chest.

OPERATIONS ON THE MEDIASTINUM

(1) Drainage of a mediastinal abscess.—Suppuration in the mediastinum is rare; when it does occur, it usually arises in the posterior mediastinum due to infection from the œsophagus. If a localized abscess forms, extrapleural drainage is indicated.

Technique.—The operation is preferably performed under general anæsthesia using an endotracheal tube in case the pleural cavity is accidentally opened.

A slightly curved incision is made, with the concavity directed laterally, running down the lateral border of the sacrospinalis muscle. The overlying extracostal muscles are divided in the line of the incision. The removal of the posterior segments of three ribs is usually sufficient to provide adequate drainage. In an adult, about 3 in. of each rib, together with the tips of the corresponding transverse processes, are resected. To do this, the sacrospinalis muscle is retracted medially but not divided. The periosteum in the medial part of one rib bed is incised so as to open the endothoracic space without opening the pleural cavity; by gentle blunt dissection the pleura is separated from the intercostal bundles and periosteum opposite the tips of the partially-resected transverse processes. The intercostal bundles are ligated and divided. With extreme care, the parietal pleura is stripped from the medial ends of the ribs and vertebral bodies with the finger.

This separation may be extended upwards and downwards deep to the intact ribs in order to increase the exposure If the pleura is torn, it should be carefully sutured while the lung is kept inflated by the anæsthetist and the wound packed; the actual drainage of the abscess should then be delayed for four or five days until the opening has become sealed off. When the abscess is reached, it should be opened up widely, the pus evacuated and the cavity insufflated with penicillin powder and then packed with dry gauze, the edges of the wound being protected with vaseline gauze. The cavity is allowed to heal from the bottom as in a lung abscess.

(2) Removal of mediastinal tumours.—With tumours in the anterior mediastinum which are considered to be of thymic or thyroid origin it is preferable to obtain exposure by splitting the sternum vertically in the mid-line; this incision provides access to the root of the neck

which may be required as these tumours are liable to obtain at least part of their blood supply from the vessels in the neck. (*See* Surgery of the thymus.)

With the above exceptions tumours of the mediastinum are best removed by a transpleural route. Those in the posterior mediastinum are best exposed by a postero-lateral thoracotomy (q.v.) adjusting the level of the incision according to the position of the tumour. Tumours situated anteriorly usually project more into one pleural cavity than the other; the side on which there is the greatest projection is then chosen for thoracotomy. It is often recommended that an antero-lateral thoracotomy should be employed for anteriorly-placed tumours such as teratomas but this recommendation is based on false reasoning for the surgeon's prime concern is to avoid damage to the important structures *which lie behind* the tumour; with an anterior incision, if the tumour is large, it very often obscures these structures whereas a postero-lateral thoracotomy provides a good exposure of the posterior relations of the tumour; thus with a posterior incision, although there may be gross distortion of the anatomy, injury to structures such as the innominate vein can usually be avoided. It is therefore suggested that it is preferable to use a postero-lateral approach for *all* mediastinal tumours unless there is good evidence that the tumour is of thymic or thyroid origin or that an anteriorly-situated tumour is unlikely to have distorted the anatomy, for example, a pleuropericardial cyst in which case an antero-lateral thoracotomy can be safely employed.

The tumour is removed by carefully separating it from the surrounding mediastinal structures. Much of the separation can usually be done by blunt dissection but adhesions carrying blood vessels must be clamped, divided and ligated. Any extension of the tumour to the opposite side of the mid-line can usually be exposed by traction on the tumour, but care should be taken to avoid opening the opposite pleural cavity if possible; if this accident does occur, it should not be of serious consequence as the anæsthetist, by using an endotracheal tube, should be in a position to keep the opposite lung inflated. Teratomas are often densely adherent necessitating much sharp dissection for their removal; the initial part of the dissection is usually easiest if the tumour is kept intact but, if the tumour is large and cystic, the later stages are often facilitated if the tumour is opened and the contents evacuated with the sucker The majority of neurogenic tumours lie in the paravertebral gutter and are not truly tumours of the mediastinum although they may extend into it; they obtain their blood supply entirely from the intercostal vessels and, if the tumour is large and firm, and particularly if it has extensions into the intercostal spaces, it may be difficult or impossible to secure the vessels supplying it while the tumour is *in situ*; in these circumstances, the tumour may be forcibly enucleated, and bleeding from the tumour bed immediately controlled by pressure with a large gauze pack, the latter is then gradually rolled back and the bleeding vessels picked up with hæmostatic forceps.

Before closing the chest after removing a mediastinal tumour a basal

intercostal drain should be inserted; this is connected to a water-seal drain and removed after 48–72 hours.

SURGICAL COLLAPSE THERAPY IN PULMONARY TUBERCULOSIS

tu

so

Reduction in the length and calibre of the bronchi in the collapsed area may also have a markedly beneficial action in promoting cavity closure for the bronchi draining a cavity are usually affected by tuberculous endobronchitis which narrows the lumen and the further narrowing which accompanies the collapse treatment may lead to complete obliteration of the lumen and subsequent healing of the cavity. *Collapse therapy is therefore essentially a treatment directed towards cavity closure and is rarely indicated in the absence of cavitation.* Very occasionally, one of the less drastic forms of collapse may be employed in the treatment of disease which is not complicated by cavitation, on the grounds that permanent healing is likely to be encouraged by the decreased function which follows the collapse.

In applying collapse treatment the clinician must always aim at conserving the function of as much healthy lung as possible.

In deciding on which method of collapse is most applicable to a given case the guiding principle should be to choose the simplest and safest *method likely to lead to permanent healing of the disease.* In applying this principle the emphasis must be placed on the object of surgery, that is, *permanent* healing, it is therefore wrong to undertake a very simple and safe measure such as phrenic paralysis if this is likely to arrest the disease only so long as a pneumoperitoneum is maintained and the patient leads a very restricted life, of course, if the patient is unfit for operative procedures necessary to produce permanent healing, *less drastic measures may be employed initially with the object of improving the patient's condition sufficiently to warrant more definitive treatment at a later date.*

Phrenic Nerve Interruption

The hemidiaphragm may be paralysed temporarily by crushing the *phrenic nerve and any accessory branches in the neck.* the paralysis so caused is of very variable duration but usually lasts for a period of between four to nine months rarely the paralysis is permanent; when this does occur it is probably the result of crushing the nerve with excessive enthusiasm. *Permanent paralysis of the diaphragm* may be induced with intent by evulsing the nerve but this once popular operation is now rarely indicated, because, if good progress is made as a result of hemidiaphragmatic paralysis caused by crushing the nerve, the paralysis can always be prolonged by repeating the crush, whereas

diaphragmatic action can never be restored when the nerve has been evulsed.

Indications.—The indications for paralysing the diaphragm in the treatment of pulmonary tuberculosis are open to a very great difference of opinion: some phthisiologists regard diaphragmatic paralysis as a useful adjunct to treatment in quite a large number of cases, whereas others consider it almost useless.

Anti-tuberculous chemotherapy has certainly almost completely replaced phrenic paralysis as a means of controlling the active progressive phase of the disease.

Phrenic paralysis may be indicated under the following circumstances:—(1) When a pneumothorax cannot be induced on account of adhesions and cavitation is present, the cavities being thin-walled and less than 2 cm. in diameter. The phrenic paralysis may then sometimes lead to permanent healing. (2) In the presence of minimal disease without cavitation. In such circumstances rest alone may lead to arrest of the disease but some authorities believe that this is more likely to occur if the diaphragm is also paralysed. (3) In patients who have extensive disease which is mainly unilateral but which is too active to justify undertaking major surgical measures such as thoracoplasty or resection. If the phrenic nerve is crushed the activity of the disease may subsequently subside sufficiently to justify a more definitive form of treatment, but, as already stated, this control of activity is usually far more easily achieved by chemotherapy so that diaphragmatic paralysis is now rarely indicated for this purpose. Phrenic paralysis may, however, be undertaken more readily when it is anticipated that the final form of treatment is likely to be resection rather than thoracoplasty, for it is usual to combine most forms of resection with phrenic paralysis,* whereas it is desirable that the diaphragm should be functioning at the time of performing thoracoplasty as collapse of the lower lobe is more frequent after an upper thoracoplasty when the hemidiaphragm is paralysed than when it is contracting. (4) In hæmoptysis uncontrolled by palliative measures. Temporary phrenic paralysis may stop the bleeding. (5) In conjunction with an artificial pneumothorax under the following circumstances:—(*a*) When adhesions to the diaphragm are preventing satisfactory collapse and especially when the lung is also adherent to the apex. (*b*) Before allowing re-expansion of a previously grossly diseased lung Diaphragmatic paralysis reduces the size of the hemithorax so that the healed lung, which is of reduced size, may be able to fill the hemithorax without undue tension on the scar tissue. This is particularly desirable if the pneumothorax has had to be abandoned prematurely. (6) When a pneumonectomy has been performed and the phrenic nerve has been left intact. The phrenic nerve is usually divided at the time of removing the lung (*see*

* Diaphragmatic paralysis used to be performed routinely at the time of doing an upper lobectomy, but the modern trend is to omit crushing the nerve.

pneumonectomy, p. 363) but it may be considered advisabl...

period. In such a case the nerve may be divided in the neck as soon as the patient is convalescent from the pneumonectomy, that is some ten days after the resection.

Anatomy.—The phrenic nerve arises from the third, fourth and fifth cervical nerves, but the contribution from the fifth root, which may arise from the nerve to subclavius, sometimes joins the main nerve very low down in the neck or even in the thorax; it is then referred to as an accessory phrenic. On occasion the accessory phrenic

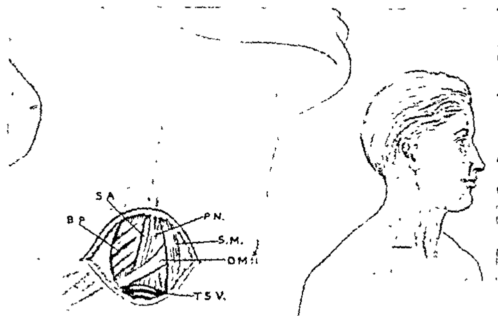


Fig. 141.—Phrenic nerve crush.

Insert shows the site of the incision The larger drawing shows the anatomy of the structures exposed.

P N.	=	Phrenic nerve.	T S V	=	Transverse cervical vessels.
S M.	=	Sterno-mastoid muscle.	B.P.	=	Brachial plexus
O M	=	Omo-hyoid muscle.	S.A.	=	Scalenus anterior

is large, in which case the main nerve is correspondingly small. Sometimes the main nerve may be found as two separate nerves running down parallel on the scalenus anterior. The exact position of the nerve also varies considerably; classically the nerve passes from the lateral border of the scalenus anterior on to the upper part of its anterior surface which it then gradually crosses to reach the medial border at the root of the neck Sometimes, however, the nerve runs down the lateral border of the scalenus anterior and does not cross medially until it is about to enter the thorax; on other occasions it crosses high up and then runs down close to the medial border of the muscle.

An accessory phrenic nerve is present in about 20 per cent. of cases.

Technique for crushing the phrenic nerve.—The patient lies on the back on a flat operating table, with the face turned to the opposite side and the shoulder depressed as far as possible. The assistant and the surgeon stand on the same side of the operating table, that is on the side to be operated on. The scalenus anterior muscle can be felt with the finger as a firm band of muscle deep to the lateral border of the sternomastoid. The skin over the area to be incised is infiltrated with 1 per cent. novocain and a few ml. are also injected under the deep fascia. A horizontal incision, one inch long, is made one inch above the clavicle (Fig. 141). The rest of the operation is done entirely by blunt dissection. The platysma and deep fascia are not divided in the line of the incision, but the muscle is split vertically in the line of its fibres with a pair of fairly fine-pointed artery forceps. This prevents not only bleeding but also subsequent widening of the scar from adhesion between the muscle and skin wounds. Two narrow-bladed retractors are used, one to each margin of the wound: it is desirable that one of these should carry a small light so that the surgeon is not dependent on " spot-lights " to provide illumination at the bottom of the wound. The surgeon holds the upper retractor on the right side and the lower one on the left, and the assistant holds the other. By blunt dissection with a pair of artery forceps, the scalenus anterior is exposed. The transverse cervical vessels and omohyoid muscle, if seen, are retracted downwards. If the surgeon sees the brachial plexus, the dissection is being carried out too far laterally; if he sees the jugular vein it is too medial. The anterior surface of the scalenus anterior is now explored to discover the nerve (Fig. 141). If it is not found in the classical position, a search should be made over the whole anterior surface of the muscle starting from the lateral border. When the nerve has been found it should be injected with a small quantity of 1 per cent. novocain without disturbing it from its position under the fascia which covers the muscle. The nerve is then crushed *once* with a narrow-bladed clamp immediately below the site of novocain injection; the length of nerve crushed should only be the breadth of the blades of the forceps, and the nerve should not be separated from the fascia covering the scalenus anterior, as a broad crush after lifting the nerve from its bed may account for those cases in which crushing results in permanent instead of temporary hemidiaphragmatic paralysis. If the crush is made at the end of expiration the diaphragm will contract strongly and cause a sudden forward movement of the abdominal wall which can easily be seen: although this contraction may be accepted as evidence that the nerve crushed is indeed the phrenic nerve it does not necessarily mean that the hemidiaphragm is now completely paralysed. However, if the nerve is not smaller than expected and if X-ray screening facilities are available close to the operating theatre, the author prefers to close the skin without searching for accessory branches and to examine diaphragmatic movement forthwith on the X-ray screen. If hemidiaphragmatic paralysis is complete, that is, the hemidiaphragm does not descend *at all* on deep inspiration, the

patient is returned to the ward. If the paralysis is not complete the patient is taken back to the theatre, the skin stitches or clips are removed and the wound is reopened. To find any accessory branches the dissection is continued downwards and laterally (through the same skin incision), so as to expose the brachial plexus which runs downwards and outwards from behind the lateral border of the scalenus anterior. The fascia over the plexus is separated and any nerve filaments which run vertically downwards parallel to the lateral border of scalenus anterior are lifted up off the plexus and divided: a short segment (about 1 cm.) of any such nerve filament should be resected to prevent regeneration. As the nerve to subclavius which arises from the upper trunk of the plexus often carries accessory phrenic fibres, this nerve should be included in those divided and resected. The skin wound is again closed with clips or very fine sutures (it is unnecessary to place any sutures deep to the skin), and diaphragmatic movement is re-examined by fluoroscopy. If paralysis is still not complete the patient must be returned again to the theatre and further search made If fluoroscopy is used in this way time will not be wasted in searching for accessory branches which may not in fact exist: it also ensures that paralysis is obtained in very nearly 100 per cent. of cases.

When permanent paralysis of the diaphragm is desired, e g. after a pneumonectomy, the phrenic nerve should be divided as high up as possible· the fibres are then dissected out to the base of the neck where they are again divided by this means it is possible to resect several centimetres of the nerve and thus exclude the chance of regeneration. Accessory branches must be treated as described above. This method is preferable to the old method of evulsing as great a length of the nerve as possible as this procedure causes pain and on very rare occasions may damage the subclavian vein

Intrapleural Pneumonolysis

Artificial pneumothorax frequently fails to give satisfactory collapse owing to adhesions between the two pleural layers, unfortunately these adhesions usually occur over that portion of the lung which it is most desired to collapse.

The type and extent of the adhesions vary widely. They are of five main kinds —(1) Thin strings which stretch easily. (2) Round, cord-like adhesions which, although tougher than the strings, often stretch to several centimetres in length. (3) Sheets which are of light texture and may be translucent. (4) Bands of dense fibrous tissue: they may be short so that the lung is held close to the chest wall but they sometimes stretch to 2 or 3 cm. in length (5) The lung may be adherent directly to the chest wall over smaller or larger areas

A radiograph of the chest taken in expiration will show the extent to which collapse is interfered with, and usually gives some idea of the type and extent of the adhesions, but their real nature can only be determined by inspection In some cases, where a few apparently easily divisible strings are seen in the X-ray film, inspection shows

extensive areas over which the lung is directly fused to the chest wall in addition to the strings. On the other hand, some cases which appear to be impossible in the X-ray film are found on inspection to have easily divisible adhesions.

Adhesions in an artificial pneumothorax which are preventing the closure of cavities must be divided if this can be done without risk: if this cannot be done the artificial pneumothorax must be abandoned forthwith as maintenance of an artificial pneumothorax without cavity closure is almost certain to lead sooner or later to the formation of a tuberculous empyema.

It has been generally accepted that, if all cavities have closed in spite of the presence of adhesions, these adhesions should nevertheless be divided if this can be done safely, in order to allow more complete collapse of the diseased area and to facilitate maintenance of the pneumothorax. In fact, sometimes it has been recommended that an artificial pneumothorax should be abandoned in spite of cavity closure if there are numerous adhesions which are indivisible. Recently Foster-Carter* has produced statistical evidence to show that the mere presence of adhesions in a pneumothorax does not impair either the efficiency of pneumothorax treatment or the long-term prognosis, *provided* all cavities were closed. Even so, it is probably advisable to continue to recommend division of adhesions even if the cavities have closed; but very careful consideration should be given before recommending abandonment of a pneumothorax because of indivisible adhesions which have not prevented cavity closure.

Closed intrapleural pneumonolysis: Thoracoscopy.—The principle of the operation is the insertion through an intercostal space of a cannula through which the thoracoscope is passed; with this instrument it is possible to inspect the whole pleural cavity and to see adhesions as the bladder is seen through a cystoscope. Various modifications of the original instrument devised by Jacobæus of Stockholm have been invented. To the right-angled viewing telescope has been added one with a terminal prism which gives a forward view of 20° from the axis. Through a second cannula in another interspace an electric cautery is introduced and used at a dull-red heat to divide the adhesions under vision. Chandler devised an instrument which carries both the telescope and cautery, and is used through a single cannula. This instrument makes division of simple adhesions a very quick procedure but it is less satisfactory for more complex adhesions.

Pre-operative considerations.—A long adhesion may be divided with much greater safety than a short one. Although adhesions should be allowed to stretch after the induction of an artificial pneumothorax, it is never justifiable to use positive pressures to make them stretch as this may cause rupture of the pulmonary attachment of the adhesion and a subsequent tuberculous empyema. The period which should be allowed for stretching varies in different cases: three to six weeks after

* *Brompton Hospital Reports*, 1952, xxi, 1.

induction of the pneumothorax is usually the most satisfactory. Some surgeons recommend thoracoscopy at a much earlier date, such as seven to ten days after induction of the pneumothorax, on the grounds that maintenance of the collapse in the presence of adhesions and unclosed cavities may lead to tuberculous infection of the pleural space, but the likelihood of complications arising within six weeks of induction is extremely remote. On the other hand it is unwise to continue with an ineffective pneumothorax for many months in the hope that the adhesions will ultimately stretch sufficiently to make division possible; it is better to abandon the pneumothorax and consider some other form of treatment.

There must be a sufficiently large pneumothorax to allow the introduction of the trocar and cannula without risk of damaging the lung. Adhesions are more readily severed if fairly taut; a refill of air should therefore be given on the day before operation. It is essential to determine the position in which the first trocar and cannula can be inserted without damage to the lung; this can usually be found from examination of a simple postero-anterior radiogram. The best position for the second cannula is decided after inspection of the adhesions through the first cannula.

Pleural fluid complicating a pneumothorax is not an absolute contra-indication to intrapleural pneumonolysis unless it contains tubercle bacilli or is causing fever.

Technique.—The patient lies on the good side with the head end of the table slightly raised; during the operation it may be necessary to elevate further the head end of the table in order that the apex of the lung may be drawn downwards by gravity from the upper part of the pleural cavity, thus improving the view of this critical area and also putting any apical adhesions under tension. The hand underneath is placed under the pillow on which the head rests, and the upper arm is drawn upwards and forwards so that the scapula is pulled anteriorly. A pillow under the side curves the spine and widens the interspaces. The sites for the insertion of the cannulæ must be chosen with due regard for the position of the adhesions as seen in a radiogram, but for the majority of cases the posterior cannula is inserted in the 5th or 6th interspace about an inch behind the vertebral border of the scapula and the anterior one in the axilla. In cases of doubt it is best to insert the axillary one first and choose the site for the second one after inspection with the thoracoscope.

At the site chosen, the skin and tissues down to the pleura are infiltrated with 1 per cent. novocain; if air is obtained by withdrawing the piston of the syringe, then the point of the needle must have passed through the parietal pleura. An incision ½ in. long is made in the skin and a pneumothorax needle inserted just into the pleural cavity; through this a blunt-ended stylet 2 or 3 in. longer than the needle is gradually advanced If the advance of the stylet is arrested by an obstruction less than 1½ in. beyond the end of the needle the site should be abandoned and another one selected. If the depth of the

pleural space has been shown in this way to be at least 1½ in., the needle and stylet are withdrawn and the trocar and cannula introduced by a steady pressure. They should not be rotated as this tends to produce a round hole in the pleura rather than a linear cut and the latter heals more readily. The trocar is withdrawn and the thoracoscope introduced. The adhesions are carefully inspected, and the operator decides whether it is possible to divide them; this is largely a matter of experience; it is wise to err on the conservative side. Unless the surgeon feels that there is a reasonable chance of being able to free the lung sufficiently to allow subsequent closure of all cavities, no section should be attempted: it is in fact stupid to divide a number of easily divisible adhesions when it is obvious that there are other indivisible adhesions which would prevent satisfactory collapse. Section should not be undertaken if there are tubercles on the pleural surface, as sooner or later these tubercles are likely to cause a tuberculous effusion.

As a general rule an adhesion should be divided close to the chest wall; this is of the utmost importance when lung tissue, which is recognizable by the pigment which it contains, extends out close to the chest wall within the adhesion. If the lung tissue extends very close to the chest wall, the safest method is to divide the parietal pleura close to the peripheral attachment of the adhesion and then strip the attachment from the chest wall with the unheated cautery (Maurer's enucleation method).

If the adhesions are vascular the vessels may be coagulated with the flat surface of the cautery before dividing them. If any vessel bleeds, the bleeding point should be controlled by pressure with the cold cautery loop and then coagulated by turning on the current. If the actual source of the bleeding is obscured by blood or clot this may be removed by suction, using a special straight metal suction tube. If this does not reveal the bleeding point a small portion of cotton wool *firmly* attached to a cotton-wool holder may be used to wipe away clot; this may also be used to apply pressure to the source of hæmorrhage until the flow of blood has diminished and become more amenable to control by coagulation.

Small cords and strings are often attached to the subclavian artery or to the mediastinum: these can often be divided more easily if they are lifted up with a cautery made in the form of a hook. If the hook tends to slip towards the lung it may be an advantage to use Maxwell's articulated hook, in which the cautery loop can be placed at right angles to the axis of the instrument by rotating a collar in the handle. If the burning of the adhesion causes pain, the peripheral attachment of the adhesion and the pleura around should be injected with novocain through a long applicator attached to a syringe, and introduced through the cautery cannula.

Exceptionally, when the adhesions are very extensive, it may be necessary to stop after they have been partly divided and to repeat the operation in a few weeks' time. Short adhesions, particularly those at the apex, may stretch during the interval and become

divisible at the second operation. However, multiple operations are now rarely justified as it is usually preferable to abandon a pneumothorax which requires extensive adhesion section in order to make it satisfactory, for there are so many alternative methods of treatment which are likely to be less dangerous.

When a bilateral pneumothorax is present, the collapse on the contralateral side should be reduced to a minimum before the patient is brought to the theatre and oxygen should be administered during the operation. If the patient becomes uncomfortably dyspnœic in spite of these precautions, one cannula should be occluded with the finger and air aspirated from the other with a sucker; the second cannula is then likewise occluded Subsequently the patient may settle down sufficiently to justify continuing the operation.

At the end of the operation any blood visible in the pleural cavity should be aspirated through the sucker as, if left, it tends to excite a pleural effusion. In many cases this blood has trickled down from the cannula puncture in the chest wall. Before withdrawing the second cannula the patient should make several forced expirations during which the cannula is left open to the atmosphere but is occluded with the finger during the intervening inspirations, by this means air is forced out of the pneumothorax space so that excessive collapse with shift of the mediastinum to the opposite side is avoided.

Finally the stab incisions are sutured and covered with gauze which is fixed tightly in position with adhesive strapping in order to prevent escape of air from the pleural space and consequent surgical emphysema.

Post-operative care.—Whenever possible the patient should be examined by fluoroscopy immediately after the operation: the collapse may then be adjusted by withdrawing air if it is excessive or by giving an air refill if it is insufficient. The patient thus starts his convalescence with the degree of collapse perfectly adjusted The patient should be nursed in the sitting position for a few days, and not allowed to lie down even for a few minutes so that any fluid which may form is prevented from entering the upper part of the chest, for this fluid may deposit strands of fibrin and if these stretch between the lung and chest wall and subsequently organize, adhesions are reformed. If adhesions have been divided posteriorly in the paravertebral gutter, particularly when placed over the apex of the lower lobe, it may be preferable to nurse the patient in the prone position in order to prevent the lung coming into contact with the raw area of the chest wall for this is likely to lead to re-adherence. An X-ray film of the chest should be taken in the ward on the following day and repeated on several further occasions during the first ten days Air refills are controlled entirely by the degree of collapse found. this degree should be greater than that ultimately required but the lung should not be rendered completely air-less. If the lung does become completely atelectatic no active steps need be taken unless the patient's temperature exceeds 101° F: in the latter case the atelectasis is

probably caused by bronchial obstruction due to retention of sputum and the patient must then be encouraged to expectorate. A small effusion which just fills the costo-phrenic sinus is usual and may be ignored, but an effusion which reaches near to the dome of the diaphragm should be aspirated as it is likely to contain blood which may stimulate the exudate of further fluid.

Open intrapleural pneumonolysis.—Open intrapleural pneumonolysis or open adhesion section signifies an operation in which the pleural cavity is opened by a small thoracotomy incision and any adhesions present are divided under direct vision. There are no longer any indications for its use.

Extrapleural Pneumonolysis

This operation gives a selective pulmonary collapse by stripping the parietal pleura from the chest wall and mediastinum over the diseased area and filling the extrapleural space thus obtained with some substance. At one time autogenous fat and pedicled muscle grafts were used to fill the space but these were abandoned in favour of paraffin wax. Wax has also been given up because of the frequency with which it ultimately perforated into the lung or through the chest wall. Air was then used to maintain the space, that is, the operation was done to obtain an extrapleural pneumothorax, refills being given as required in a manner similar to that used for the maintenance of an intrapleural pneumothorax.

In recent years some of the relatively inert plastic materials were used to fill the space but the incidence of late complications was again high; separation in the *extrapleural* plane is therefore no longer employed if these materials are going to be used to maintain the collapse (*see* thoracoplasty with plombage, p. 419). Thus, extrapleural pneumonolysis is now only performed when it is intended to maintain the space with air refills but some surgeons feel that even this method of collapse should be entirely abandoned because of the risks of hæmorrhage into the space and of tuberculous infection in it. In the author's opinion it is still a useful method of collapse in a very small selected group of patients, that is, for those in which an intrapleural pneumothorax is highly desirable but unobtainable or unsatisfactory. Thus, it may be used to treat bilateral upper lobe disease which has been present for less than three years and in which small cavities persist in spite of rest and chemotherapy. It may also be indicated in young patients (i.e. those under 21), particularly females, with unilateral upper lobe cavitation for which temporary collapse may be preferred to permanent measures such as thoracoplasty owing to the possibility of disease appearing later in other parts of either lung. On occasion it may be employed in patients who are unfit for more radical measures because of complicating factors such as asthma, uncontrolled tuberculous enteritis or amyloid disease Extrapleural pneumonolysis should never be performed for chronic disease with much fibrosis or in the presence of large cavities.

Technique.—General anæsthesia is preferable as respiration can then be controlled and excessive movement eliminated; this helps the surgeon to avoid tearing the parietal pleura. The gas mixture used for anæsthesia should not be explosive so that diathermy may be used for hæmostasis when required. If local anæsthesia is used the patient frequently suffers

bouts of coughing while the pleura is being stripped from the mediastinum: this may also happen under general anæsthesia if the depth of narcosis is not increased during this phase of the operation.

The patient lies on the good side with the uppermost scapula elevated and rotated as far forwards as possible. This position brings the vertebral border of the scapula to overlie and run parallel with the third intercostal space, so that the posterior part of the fourth rib is no longer covered by it A 5-in. incision is made over the fourth rib, the inferior fibres of the trapezius divided at the medial end of the incision and the rhomboid major split in the line of its fibres. The serratus posterior superior is separated from its attachment to the fourth and fifth ribs and retracted. A 5-in. segment of the fourth rib is subperiosteally resected, extending back to the transverse process. This should be done with great care to avoid damage to the parietal pleura. If the periosteum which lay on the deep surface of the portion of rib removed has not been already torn during the process of rib resection, it must be incised cautiously so as to expose the parietal pleura. *The intercostal tissues of the interspace above are now lifted gently* with tissue forceps and the parietal pleura separated from their deep surface with a blunt instrument. It is now usually possible to continue the separation of the parietal pleura from the chest wall with the finger: when the pleura has been detached all round the wound, there is a sufficient extrapleural space to continue the separation under direct vision. The upper margin of the periosteum and adjacent intercostal muscles are retracted with two small double-hook retractors. A retractor shaped like a spatula and carrying a light at the end is introduced and used to hold the lung down while the separation of the pleura is continued under vision with a small gauze swab held in a long hæmostatic clamp. Below the wound it is often easiest to strip the pleura from the chest wall with the finger but obviously this method cannot be continued beyond the length of the finger. Bleeding may occur from vessels in the chest wall, particularly in the neighbourhood of the internal mammary vessels and at the posterior ends of the intercostal spaces. The bleeding points should be coagulated with the diathermy current as they arise: if this is done, post-operative hæmorrhage is less likely than if hæmostasis is left until the separation of the pleura has been completed. Bleeding from sites unsuitable for coagulation, for example, in proximity to large vessels, may be controlled with neural clips. Care should be taken to keep the separation to the extrapleural plane; if an area is particularly firmly adherent it should be isolated by freeing the pleura all round it; subsequently it is usually possible to free the adherent area without difficulty. If the lung is extensively fused to the chest wall so that there is a tendency to strip intercostal structures from the chest wall, it is almost certain that the pulmonary disease is too chronic to be suitable for extrapleural pneumothorax: in these circumstances it is better to abandon the extrapleural pneumonolysis and replace it by some other procedure such as thoracoplasty or extraperiosteal plombage. It is important that the pleura should be stripped down to the hilum on the mediastinal surface, down to the eighth or ninth rib posteriorly, and to the third or fourth costal cartilage anteriorly. This allows for partial re-expansion of the lung, which always follows the operation. Failure to close pulmonary cavities is usually due to inadequate separation.

Before closing the chest the space is washed out with 1 : 4,000 euflavine solution so that all fluid and clotted blood is removed. The space is then examined meticulously to discover any bleeding points which have escaped

previous attention for it is essential that the walls of the space should be left absolutely dry.

The incision in the intercostal muscle and rib bed is repaired with a continuous nylon suture; this should be done with great care in order that air may not escape into the chest wall after operation. Finally the extracostal muscles and skin are approximated with continuous nylon sutures.

Post-operative care.—The patient is kept sitting up in bed. A radiogram is taken on the day after operation and about every third day for the next fortnight. The frequency and size of air refills depend entirely on the X-ray appearances. It is desirable that the extent of the collapse should exceed that ultimately required for some re-expansion will occur during the next month or two, even if most determined efforts are made to keep it down with frequent refills. Many surgeons recommend frequent refills and high final pressures but these are rarely necessary. If the intercostal space was sutured while the pressure in the anæsthetic circuit was low so that the lung was well collapsed, the X-ray film taken the day after operation commonly shows that the collapse is quite adequate. Provided the patient does not develop any surgical emphysema, it is often unnecessary to give a refill for a week or more.

When a refill is given the needle should be passed through the first or second intercostal space anteriorly. This is preferable to using the axilla for refills as there is quite frequently a fairly large vessel which runs vertically down inside the chest in the mid-axillary line; injury to this vessel may account for some cases of post-operative hæmorrhage into the pneumothorax.
The amount
if it occupies
but this need
not be repeated even if the fluid recurs provided the proportion of blood in the fluid is not great. Heavily blood-stained fluid is likely to deposit much fibrin which may organize and lead to obliteration of the space but fluid which contains only a small proportion of blood is almost invariably absorbed completely without much fibrous tissue formation.

Post-operative complications. (1) *Hæmorrhage.*—This may be a slow oozing which gradually fills up the space: in this case the blood should be aspirated: if clot prevents aspiration, the clot should be broken up with streptokinase (p. 324) about 10–14 days after operation and the fluid aspirated subsequently: if this is not successful, a portion of rib should be resected high up in the axilla and the remaining clot evacuated.

In some cases there is serious delayed hæmorrhage, most commonly about 36 hours after operation. This may demand immediate blood transfusion. If the mass of blood in the space gives rise to pressure symptoms, some of it should be aspirated but only sufficient to relieve the patient's symptoms. The rest of the blood may be removed later as described above.

(2) *Interstitial emphysema.*—A small quantity of air in the upper part of the chest wall and base of the neck is common and may be ignored. If the patient has much cough and if the incision in the rib bed has been carelessly sutured, the patient may develop gross emphysema with great puffiness of the face and swelling of the eyelids so that the eyes are closed. This is distressing to the patient and alarming to view but is of no serious consequence. On the other hand maintenance of the extrapleural space in such cases may be difficult and require frequent refills.

(3) *Pyogenic infection of the space.*—This is rare. If it occurs, the

infection should be eradicated whenever possible by appropriate chemotherapy, and the space subsequently maintained with air refills. If the infection cannot be des [illegible]
obliterated by removing [illegible]
into a thoracoplasty. I [illegible]
is so depressed by the *infection that thoracoplasty cannot be undertaken* safely. In these circumstances the extrapleural space must be drained externally by rib resection (as for an empyema, q.v.), and a thoracoplasty performed later. External drainage should not be *employed as a preliminary* measure unless it is necessary for it is liable to lead to infection of the subsequent thoracoplasty wound.

(4) *Tuberculous infection of the space.*—Tuberculous infection may occur at any time, sometimes more than a year after the original operation. Its onset is an urgent indication for thoracoplasty. As this complication is not uncommon some surgeons advise thoracoplasty in all adult patients who have been treated by extrapleural pneumothorax as soon as the pulmonary disease has become stabilized.

Thoracoplasty

Thoracoplasty in its modern form has proved to be one of the most satisfactory methods of collapse without carrying undue risk to the patient. Follow-up study of tuberculous patients treated by collapse therapy has shown that there is less likelihood of re-activation of the tuberculosis after thoracoplasty than after temporary forms of collapse such as pneumothorax. Nevertheless, the operation should only be undertaken after careful consideration of each individual patient by one experienced in the selection of cases, with particular reference to the following points:

(1) **Age.**—The best results have been obtained in patients between 30 and 40; patients under 30 have on the average less resistance to the disease than those of the fourth decade. The hazards of the operation become progressively increased after the age of 40 but good results have been obtained up to the age of 60. However, the older age group withstand resection better than thoracoplasty and this should be borne in mind when deciding treatment. Nevertheless, no patient between 20 and 60 in whom the operation is indicated should be refused on account of age alone.

(2) **General condition.**—An ambulant patient in whom the general cardio-vascular tone has been maintained is a much better risk than a patient who has been confined to bed for a long period. An estimate of cardio-respiratory reserve must be based on dyspnœa and cyanosis, the pulse rate at rest and after walking exercise, the blood pressure, the amount of chest expansion and the vital capacity, maximum breathing capacity, and other lung function tests. Clubbing of the fingers suggests superadded broncho-pulmonary suppuration and is usually a warning against thoracoplasty.

(3) **Type and distribution of the disease.**—Patients with unilateral disease will obviously give the best results, however, bilateral disease

is not necessarily a contra-indication, and thoracoplasty may even be combined with some form of selective collapse on the opposite side such as a pneumothorax. The pulmonary lesion should be in the productive or fibrotic phase, i.e. the patient should be showing some attempt at spontaneous healing by fibrosis but, ideally, the operation should not be delayed until there is gross fibrosis with marked shift of the mediastinum and narrowing of the intercostal spaces, as the cavities may then be so thick walled that their closure is difficult to achieve. Although thoracoplasty is primarily designed to close cavities in fibro-cavernous tuberculosis, a certain amount of associated infiltrative disease is not necessarily a contra-indication.

Giant cavities, tension cavities, cavities in the lower lobe where the upper lobe is healthy, disease which has caused complete destruction of one lung or is associated with gross secondary bronchiectasis or with marked stenosis of a main or lobar bronchus, and solid foci are all contra-indications to thoracoplasty, for these lesions are more satisfactorily treated by resection (p. 358).

Examination of serial radiograms taken during an essential pre-operative period of sanatorium treatment is of the greatest value in determining the type of disease present. Further information about the activity of the lesion must be obtained from the general appearance of the patient, temperature chart, erythrocyte sedimentation rate and differential white blood count

(4) **Suitability for other forms of collapse.**—In general, if the disease appears amenable to treatment by intrapleural pneumothorax this should be attempted before advising thoracoplasty. However, where the cavernous lesion is restricted to the apex of the upper lobe on one side, there is a growing tendency to perform an upper thoracoplasty with apicolysis, without first attempting an artificial pneumothorax, on the grounds that the operative mortality is very low and the patients avoid the necessity for keeping a pneumothorax for several years and then being faced with the difficulty of terminating it. If a patient is a suitable candidate for thoracoplasty there is no doubt that extra-pleural pneumothorax (p. 403) should not be chosen in its place in order to avoid deformity, for the long-term complications of extra-pleural pneumothorax are infinitely more frequent than those of thoracoplasty Likewise, in the author's opinion, thoracoplasty with plombage (p. 419) should only be used as a substitute for thoracoplasty when the patient is considered a " poor risk " for thoracoplasty, because the long-term prognosis after plombage remains uncertain. This is not to deny that plombage may ultimately replace thoracoplasty entirely, but this should not occur until it has been shown that the incidence of late complications is low.

General principles of the operation.—The operation has the common object of all forms of collapse therapy—cavity closure with preservation of the maximum amount of healthy lung. When the disease is spread throughout one lung, the whole of that side must be collapsed by

removal of the ribs down to and including the 9th and even 10th ribs But *when it is limited to the upper portion, as so commonly happens*, it is only necessary to collapse the upper affected part, leaving the lower part to carry on its normal respiratory function.

The collapse provided should not be in one plane only but concentric towards the hilum. It is for this reason that the vast majority of thoracoplasties should be combined with apicolysis, which involves freeing the apex from its attachments at the root of the neck, thus allowing shrinkage in the vertical as well as the horizontal plane. This important addition to thoracoplasty has been popularized by Holst and Semb.

Maximum collapse of the diseased area must be obtained at minimum risk to the patient. The operation is therefore divided into stages, as it has been found that if no more than three ribs are removed at a single stage the risk is very small, whereas removal of more involves an increased risk, proportionate to the number removed. The danger of removing too many ribs at one operation arises from the paradoxical movement of the decostalised part of the chest wall during the early post-operative period. The stages should always be arranged from above downwards, the first stage, therefore, being removal of the upper three ribs.

To obtain adequate collapse, the whole of the 1st rib, together with part of its cartilage, the whole of the 2nd rib and the major portion of the 3rd rib (in each case excluding the head and neck which lie medial to the transverse process) must be removed. Below this, the length of each rib removed is graded according to the extent of collapse required. Sufficient lengths of ribs may be removed from behind *through a parascapular incision* At one time subsidiary operations through anterior or axillary incisions were employed on some occasions in order to remove the anterior rib stumps but these operations are now recognized to be unnecessary and have been abandoned. The removal of the transverse process of some of the dorsal vertebræ was also recommended when an extreme degree of collapse was desired but this procedure leads to a marked increase in the amount of scoliosis and should never be performed.

Pre-operative preparation.—All patients should have a period of sanatorium treatment before operation. The duration depends on the activity of the lesion when the patient comes under care. If the disease is already in the fibro-cavernous stage and showing little evidence of activity, a few weeks only are required. When activity is more marked, a longer period is required and rest treatment may be combined with anti-tuberculous chemotherapy. On the other hand, streptomycin and *para*-aminosalicylic acid (or, alternatively, isoniazid) should not be given as a routine prior to thoracoplasty but should be used for a specific purpose, such as to diminish the activity of the disease or to reduce the size of large cavities.

Rarely when medical measures alone fail to produce sufficient

improvement the addition of temporary phrenic paralysis may do so; by this means a few patients in whom thoracoplasty would not at first appear justifiable, owing to the risk involved, may be rendered suitable for the operation. It is wise, however, to have the diaphragm contracting again before proceeding.

Anæsthesia.—The operation may be performed under local or general anæsthesia. The better method is the one that shows a smaller incidence of post-operative spread. The advocates of local anæsthesia claim that spread by inhalation must be less when the patient remains conscious (although adequately sedated) and in possession of intact reflexes. The advocates of general anæsthesia maintain that the skilful use of modern methods, combined when necessary with bronchial aspiration, give results that are quite as good, and the patient and surgeon are spared what is sometimes a considerable ordeal. General anæsthesia consists of minimal narcosis with thiopentone perhaps with pethidine in addition, adequate relaxation to control the cough reflex, and assisted or controlled ventilation with a fifty per cent. nitrous oxide-oxygen mixture by the absorption technique through an endotracheal tube. When local anæsthesia is used the patient should be well sedated but must remain co-operative. A paravertebral block to cover the ribs to be resected is performed with a long-acting analgesic, preferably xylocaine, and, in the case of a first stage thoracoplasty, the brachial plexus must be blocked as well. The soft tissues down to the ribs are then infiltrated in the line of the incision to complete the anæsthesia: this also serves to reduce subsequent blood loss as the injected solution should contain a very low concentration of adrenaline. When general anæsthesia is employed, the loss of blood may be similarly decreased if the soft tissues in the line of the incision are infiltrated with 1 : 250,000 adrenalin solution. For all first-stage operations, an intravenous infusion should be set up before starting the operation so that blood may be transfused as required: this is also desirable for many second-stage operations if general anæsthesia is used.

Position on the table.—The patient lies on the good side with a rubber cushion under the middle of the thorax so that the uppermost intercostal spaces are widened. The legs are placed as in the "kidney position", the upper straight and the lower flexed. The upper arm is drawn forwards and supported by a nurse who sits opposite the patient's face. The patient is prevented from rolling forwards by a special padded support which is attached to the operating table. The table is tilted into a 15° Trendelenburg position so that any secretion expressed by collapsing the lung may gravitate towards the trachea and be removed by a suction catheter passed down the endotracheal tube

First-stage operation.—A J-shaped incision is made, the vertical part commencing on a level with the first dorsal spinous process and running vertically downwards 1 in. lateral to the mid-line; it curves forwards

removal of the ribs down to and including the 9th and even 10th ribs. But when it is limited to the upper portion, as so commonly happens, it is only necessary to collapse the upper affected part, leaving the lower part to carry on its normal respiratory function.

The collapse provided should not be in one plane only but concentric towards the hilum. It is for this reason that the vast majority of thoracoplasties should be combined with apicolysis, which involves freeing the apex from its attachments at the root of the neck, thus allowing shrinkage in the vertical as well as the horizontal plane. This important addition to thoracoplasty has been popularized by Holst and Semb.

Maximum collapse of the diseased area must be obtained at minimum risk to the patient. The operation is therefore divided into stages, as it has been found that if no more than three ribs are removed at a single stage the risk is very small, whereas removal of more involves an increased risk, proportionate to the number removed. The danger of removing too many ribs at one operation arises from the paradoxical movement of the decostalised part of the chest wall during the early post-operative period. The stages should always be arranged from above downwards, the first stage, therefore, being removal of the upper three ribs.

To obtain adequate collapse, the whole of the 1st rib, together with part of its cartilage, the whole of the 2nd rib and the major portion of the 3rd rib (in each case excluding the head and neck which lie medial to the transverse process) must be removed. Below this, the length of each rib removed is graded according to the extent of collapse required. Sufficient lengths of ribs may be removed from behind through a parascapular incision. At one time subsidiary operations through anterior or axillary incisions were employed on some occasions in order to remove the anterior rib stumps but these operations are now recognized to be unnecessary and have been abandoned. The removal of the transverse process of some of the dorsal vertebræ was also recommended when an extreme degree of collapse was desired but this procedure leads to a marked increase in the amount of scoliosis and should never be performed.

Pre-operative preparation.—All patients should have a period of sanatorium treatment before operation. The duration depends on the activity of the lesion when the patient comes under care. If the disease is already in the fibro-cavernous stage and showing little evidence of activity, a few weeks only are required. When activity is more marked, a longer period is required and rest treatment may be combined with anti-tuberculous chemotherapy. On the other hand, streptomycin and *para*-aminosalicylic acid (or, alternatively, isoniazid) should not be given as a routine prior to thoracoplasty but should be used for a specific purpose, such as to diminish the activity of the disease or to reduce the size of large cavities.

Rarely when medical measures alone fail to produce sufficient

improvement the addition of temporary phrenic paralysis may do so; by this means a few patients in whom thoracoplasty would not at first appear justifiable, owing to the risk involved, may be rendered suitable for the operation. It is wise, however, to have the diaphragm contracting again before proceeding.

Anæsthesia.—The operation may be performed under local or general anæsthesia. The better method is the one that shows a smaller incidence of post-operative spread. The advocates of local anæsthesia claim that spread by inhalation must be less when the patient remains conscious (although adequately sedated) and in possession of intact reflexes. The advocates of general anæsthesia maintain that the skilful use of modern methods, combined when necessary with bronchial aspiration, give results that are quite as good, and the patient and surgeon are spared what is sometimes a considerable ordeal. General anæsthesia consists of minimal narcosis with thiopentone perhaps with pethidine in addition, adequate relaxation to control the cough reflex, and assisted or controlled ventilation with a fifty per cent. nitrous oxide-oxygen mixture by the absorption technique through an endotracheal tube. When local anæsthesia is used the patient should be well sedated but must remain co-operative. A paravertebral block to cover the ribs to be resected is performed with a long-acting analgesic, preferably xylocaine, and, in the case of a first stage thoracoplasty, the brachial plexus must be blocked as well. The soft tissues down to the ribs are then infiltrated in the line of the incision to complete the anæsthesia: this also serves to reduce subsequent blood loss as the injected solution should contain a very low concentration of adrenaline. When general anæsthesia is employed, the loss of blood may be similarly decreased if the soft tissues in the line of the incision are infiltrated with 1 : 250,000 adrenalin solution. For all first-stage operations, an intravenous infusion should be set up before starting the operation so that blood may be transfused as required: this is also desirable for many second-stage operations if general anæsthesia is used.

Position on the table.—The patient lies on the good side with a rubber cushion under the middle of the thorax so that the uppermost intercostal spaces are widened. The legs are placed as in the "kidney position", the upper straight and the lower flexed. The upper arm is drawn forwards and supported by a nurse who sits opposite the patient's face. The patient is prevented from rolling forwards by a special padded support which is attached to the operating table. The table is tilted into a 15° Trendelenburg position so that any secretion expressed by collapsing the lung may gravitate towards the trachea and be removed by a suction catheter passed down the endotracheal tube.

First-stage operation.—A J-shaped incision is made, the vertical part commencing on a level with the first dorsal spinous process and running vertically downwards 1 in. lateral to the mid-line; it curves forwards

about 3 in. below the inferior angle of the scapula almost to the mid-axillary line (Fig. 142).

The trapezius, rhomboid muscles and latissimus dorsi are divided in the line of the skin incision, thus exposing the chest wall The posterior border of serratus anterior as it descends from the inferior angle of the scapula is exposed at the anterior end of the incision but it should *not* be divided (Fig. 143). The assistant manually raises the vertebral border of the scapula from the chest wall; the costal surface of the serratus anterior is exposed by division of a little loose connective

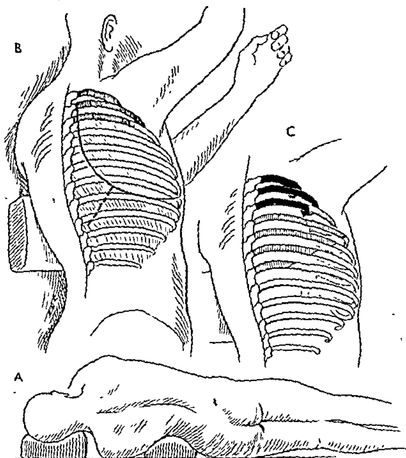


Fig. 142.—Thoracoplasty.

tissue which connects it to the chest wall The lateral cutaneous branch of the third intercostal artery and its accompanying vein and nerve are then exposed in the interval between the third and fourth digitations of serratus anterior, and are divided between ligatures. A pair of blunt-pointed scissors is insinuated between the third and fourth digitations of serratus anterior and the interval widened by separation of the scissor blades so as to allow the passage of a finger anterior to the upper three digitations; with the finger in this position so as to

protect the axillary structures, the upper fibres are divided with scissors or the diathermy current at their costal origin (Fig. 144). The scapula can then be farther elevated from the chest wall. The fleshy part of serratus posterior superior is removed as it covers the posterior ends of the upper ribs. The insertion of the scalenus posterior is detached from its insertion into the posterior part of the second rib.

A small incision is made along the lateral border of the sacrospinalis muscle so as to separate it from the third rib and the muscle is retracted

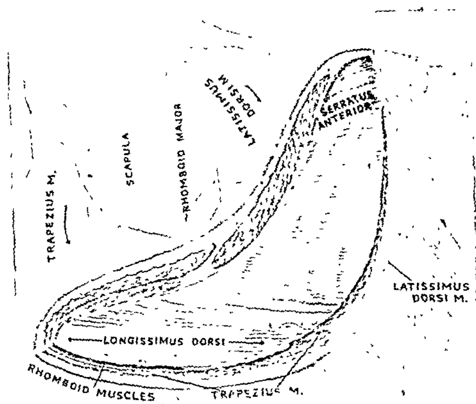


Fig. 143.—Thoracoplasty incision (right).

The shoulder girdle muscles have been divided so as to permit elevation of the scapula from the chest wall.

with two small hook retractors by a second assistant; the periosteum of this rib is divided longitudinally with the diathermy needle from the tip of the corresponding transverse process, forwards to the mid-axillary line. Working backwards along the lower border and forwards along the upper border, the periosteum is stripped from the external surface and two borders of the rib with a rugine. Separation of the periosteum is completed by stripping it from the internal surface of the rib with a curved rugine or Doyen's raspatory taking the greatest care to avoid damage to the und...
divided posteriorly o
again laterally in the

is removed in an exactly similar manner, except the division anteriorly should be actually at the costo-chondral junction.

The outer border of the first rib can now readily be felt. The intercostal tissues of the first interspace are depressed with a gauze swab held in the fingers of the left hand and an incision made through the periosteum covering the outer border with the diathermy needle. The periosteum is elevated from the outer border and inferior surface with a rugine. With the rib thus exposed to view, the periosteum is elevated from its upper surface with a special angulated rugine from

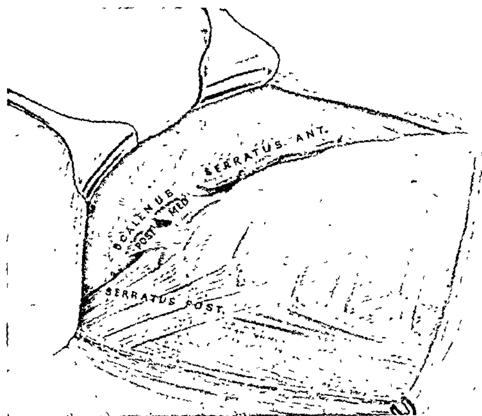


Fig. 144.—First-stage thoracoplasty (right).
The scapula is elevated to expose the upper ribs

behind forwards. Separation of the periosteum from the upper surface of the anterior part of the rib is made much easier if the posterior end of the rib is first freed completely from its periosteal covering and then divided so that it may be grasped with a pair of bone-holding forceps and drawn downwards away from the neck.

Isolation of the rib is completed by separation of the periosteum along the inner border with a long rugine: if the periosteum is very firmly attached at the site of insertion of scalenus anterior this muscle may be divided close to the rib with scissors. Special care should be taken to avoid injury to the subclavian vessels and the first thoracic nerve which are all in direct relation to the first rib; there is, however, no likelihood of damage to these structures if the rugine is *kept strictly*

in the subperiosteal layer. The rib is finally removed by division of the costal cartilage just medial to the costo-chondral junction.

Since vertical as well as horizontal collapse is desirable in order to ... cavities, the apex of the lung should ... o the neck and mediastinum in most, ... ," should be carried out in the extra-fascial plane, that is, external to the extrapleural fascia: it must be admitted that this fascia may be hardly appreciable on the mediastinum and over the vertebral column if there has not been much pleural reaction to the pulmonary disease.

To perform the apicolysis, the apex of the lung covered with the

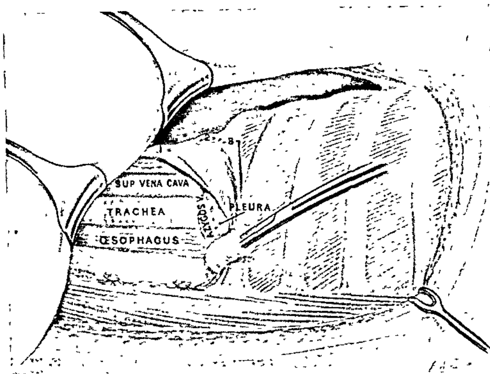


Fig. 145.—First-stage thoracoplasty (right).

The whole of the first and second ribs and the posterior half of the third rib have been removed and the lung mobilized down to the azygos vein

periosteum of the first three ribs and the intervening intercostal bundles is depressed with the left hand. this brings into prominence certain bands of fibrous tissue anchoring the lung to the root of the neck. these bands have been defined by anatomists and each labelled according to its position· in practice, these fibrous attachments appear to vary somewhat in position although two are usually found posteriorly adjacent to the first thoracic nerve. All such bands are divided, after ascertaining that no important structure is incorporated: only those that bleed after division are clamped and ligated. The apex is thus entirely liberated. The parietal pleura is now freed from the upper part of the mediastinum; this can usually be done by blunt

dissection using a small pledget of gauze held in a long hæmostatic clamp but there may also be fibrous strands requiring division with scissors. This separation is extended backwards over the vertebral column until the posterior end of the first intercostal bundle is encountered: this bundle is divided posteriorly between ligatures. The separation from the mediastinum is continued down to the aortic arch on the left and the azygos vein on the right, the second and third intercostal bundles being divided posteriorly between ligatures as the separation proceeds. The apex is thus depressed to a horizontal plane on a level with the posterior end of the unresected fourth rib (Fig. 145). Thus, when the wound is closed, there is a large space above the apex of the lung containing air and blood-stained serum which are very gradually absorbed. This results in some re-expansion of the lung but only to a slight extent as the periosteum which remains attached to it reforms bone, thus anchoring the lung down in its new position.

The operation is completed by approximating the extracostal muscles with a continuous nylon suture and closing the skin in a similar manner. No drainage is employed. A dressing is applied and, with a cotton-wool pad in the axilla and below the clavicle, the chest is firmly strapped with elastoplast in order to prevent paradoxical movement during respiration.

Second-stage operation.—There are very few cases in which sufficient collapse is obtained by the first-stage operation. The extent of further rib resection must be decided from careful consideration of radiographs taken before the first stage. As a general rule, it is necessary to extend the decostalization down to include two ribs below the lowermost limit of any cavitation present: owing to the oblique course of the ribs the posterior ends are on a much higher horizontal plane than the anterior ends; it is, therefore, the posterior segments of the ribs which must be considered in relation to any cavities present. X-ray films taken after the first stage may also be of value in determining how much more collapse is required. A thoracoplasty operation should never be completed by removing six ribs as the inferior angle of the scapula is then likely to impinge on the unresected seventh rib and cause pain, elevation of the scapula and scoliosis: if the amount of collapse desirable appears to require the removal of six ribs, the seventh rib must also be sacrificed even if this involves producing more collapse than is necessary.

The interval between the first and second and any subsequent stages varies with the individual patient. In the average uncomplicated case, an interval of three weeks between the first and second stages and of two weeks between the second and third stages usually proves most satisfactory. If the patient is not fit to undergo another operation after the expected interval, the next stage must be delayed.

The anæsthesia and position on the table are similar to those of the first stage. The previous skin and extracostal muscle incision is re-opened, with the exception of the upper two inches The scapula is

raised by an assistant, and adhesions which have formed between it and the chest wall are broken down manually (Fig. 146). The fibrous tissue septum which separates the operative field from the apical pocket of blood-stained serum resulting from the first stage apicolysis is broken with the finger and the fracture extended forwards over the external surface of the anterior remnant of the third rib. There is now adequate exposure of the remaining ribs down to the eighth or ninth. Starting with the fourth rib, decostalization is carried out in a manner exactly similar to that in which the third rib was removed at the first stage. By

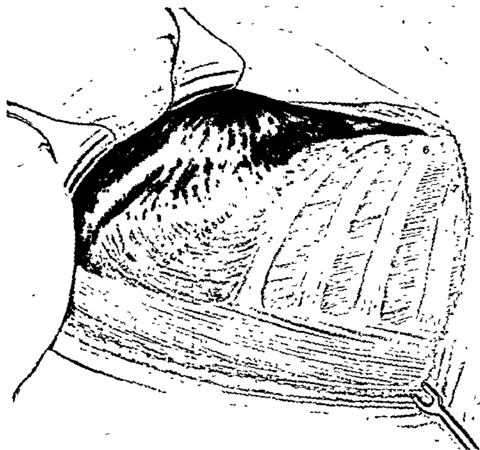


Fig. 146.—Second-stage thoracoplasty.
The original incision has been re-opened and the scapula lifted from the chest wall

retracting the spinal muscles, each rib is divided posteriorly flush with the tip of the transverse process. The position of division anteriorly depends upon the size and distribution of cavities present: large cavities and those seen to extend anteriorly in a lateral radiogram require removal of long lengths of the ribs; when there is no very large cavity and the cavitation is confined to the upper half of the lung posteriorly, the point of division anteriorly is graded from above downwards, in an average case, three-quarters of the fourth rib, two-thirds of the fifth, half of the sixth and one-third of the seventh are removed. Finally the anterior end of the third rib, which was left

in situ at the first stage in order to prevent excessive paradoxical movement, is removed right up to its cartilage (Fig. 147).

In the majority of cases there is now sufficient collapse to provide cavity closure but, if there are relatively large cavities present, it is desirable to increase the collapse still further. This may be done by incising the periosteum of the fourth rib close to the site where it has been divided posteriorly and carefully freeing the fourth intercostal bundle in the extra-fascial plane: the bundle is divided between

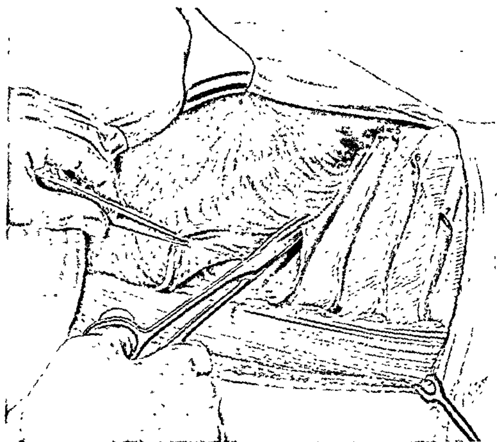


Fig. 147.—Second-stage thoracoplasty (right).

The anterior end of the third rib and portions of the fourth, fifth, sixth and seventh ribs have been removed. The scar tissue covering the old clot left over from the first-stage operation is being excised.

ligatures. The lung can then be freed further by separating the parietal pleura from the paravertebral gutter and extending this plane of separation upwards into the previous apicolysis space. This remobilization of the apex at the second stage may be still further increased by freeing the apex again from the mediastinum and by dividing more of the intercostal bundles below the fourth, but, in the author's opinion, extensive remobilization is rarely required as it is usually preferable to treat large cavities by resection.

The wound is closed without drainage as in the first stage and the chest again strapped firmly to prevent paradoxical movement.

Third-stage operation.—Further decostalization must be controlled entirely according to the collapse necessary to close any residual cavities. The lower ribs are best exposed by opening up the lower half of the old wound; in addition, an incision at right angles to this is made running downwards and backwards through the skin and extra-costal muscles (Fig. 142). Removal of the ribs is carried out exactly as before; if complete collapse of the whole lung is required, the decostalization must extend down to and include the ninth or even the tenth rib. Three-stage operations are now rarely performed as disease which is so extensive as to require such radical collapse is usually treated by pneumonectomy.

Post-operative care.—If the patient's condition is entirely satisfactory at the end of the operation the intravenous infusion may be discontinued before returning the patient to the ward; otherwise it is wise to continue the infusion with glucose-saline solution so that further transfusion may be given later if required. Oxygen should be given through a B.L.B. mask if there is any cyanosis or dyspnœa but this is rarely required in conscious patients.

The patient is initially placed lying flat on the back but, as soon as the blood pressure has returned to normal and the patient has become fully conscious, the head and trunk should be raised to the semi-sitting position. Analgesic drugs such as morphine or pethidine are required to relieve the pain in the early post-operative period, this is important as it is essential that the patient should keep the bronchial tree free from secretions by coughing and this is impossible if the pain is severe: on the other hand, excessive quantities of analgesic drugs may depress the cough reflex to such an extent that the patient has no desire to clear the air-passages of secretion: the dosage must therefore be neither too small nor too large.

The patient should be encouraged to keep the bronchial tree free from sputum throughout convalescence: expectoration may be much assisted if the nurse or physiotherapist applies firm manual pressure to the decostalized part of the chest wall so that paradoxical movement is controlled during the act of coughing. Postural drainage should also be used to help maintain a clear air-way: all pillows except one are removed and the foot of the bed is raised for half an hour three times a day, the patient lying alternately on the side of operation and on the "good" side.

Many surgeons recommend the routine administration of systemic penicillin during the first post-operative week in order to diminish the risk of wound infection and to decrease the incidence and severity of secondary bronchial infection. Anti-tuberculous chemotherapy should be reserved for those few cases in which acute spread or reactivation occurs as there is evidence that its routine use does not decrease the incidence of these complications.

As the physical signs during the early post-operative period are difficult to interpret, it is wise to make a practice of obtaining X-ray

films of the chest on the first, third and seventh day following operation: these should be taken without removing the patient from his bed.

The physiotherapist should visit the patient twice daily commencing on the first post-operative day in order to restore full movement of the shoulder-girdle and to correct the tendency towards the development of scoliosis.

Complications. (1) Hæmorrhage into the subscapular space.—There is always a large effusion of blood-stained fluid into the subscapular space but, if this is excessive, the patient may become dyspnœic and experience a sensation of great constriction on the side of operation. The pectoral muscles will then be seen to bulge forwards below the clavicle and the sutured muscles posteriorly may ride on a cushion of fluid. The excess of fluid may be confirmed radiologically. In these circumstances a large bore needle should be inserted through the pectoral muscles into the space and the fluid aspirated until there is an appreciable depression below the clavicle. Rarely bleeding is so massive that further blood transfusion is required but it is most exceptional for the bleeding to continue to such an extent that it is necessary to reopen the wound, evacuate the blood and control the source of hæmorrhage.

(2) Infection of the subscapular space.—Theoretically pyogenic infection of the subscapular space should never occur, but this serious complication does arise on occasion. It should be suspected in any case of unexplained and relatively high fever occurring during the first fortnight after operation. It is usually accompanied by an increase in the amount of fluid in the space which may be recognized clinically and radiologically. Some of the fluid should be aspirated forthwith for bacteriological examination. If the presence of infection is confirmed the bacteria can usually be eradicated by intensive local and systemic chemotherapy. If this fails, it may be necessary to drain the space through the axilla but this should be the last resort as it is certain to be followed by a purulent discharge for many months or even years.

Tuberculous infection of the subscapular space may also occur but usually arises later and is a less acute process than pyogenic infection. Commonly the wound breaks down leaving one or more discharging sinuses. If the infection cannot be eradicated with anti-tuberculous chemotherapy, the space should be drained in the axilla.

(3) Homolateral pulmonary collapse.—Collapse of the whole lung on the side of operation due to obstruction of the main bronchus with sputum is most commonly seen about 48 hours after operation but it may occur any time during the first post-operative week. It is essential that such collapse should be recognized within a few hours of its occurrence so that immediate steps may be taken to obtain re-expansion. The air-entry at the base on the side of operation should therefore be examined at least twice daily; if the breath sounds are absent the chest should be examined radiologically. If this confirms

the presence of collapse, the patient must make every effort to restore the air-way by expectoration; this may be facilitated by giving steam inhalations followed by further posturing. If re-aeration of the lung is not achieved within six hours, bronchoscopy should be performed and the secretions aspirated.

(4) **Spread of tuberculosis to previously healthy areas of lung or acute reactivation of pre-existing disease.**—Such acute processes may occur either at the base on the side of operation or on the opposite side. Anti-tuberculous chemotherapy should be started as soon as the condition is recognized and maintained until the new disease has either resolved or become quiescent.

(5) **Pneumothorax or hæmopneumothorax.**—If the parietal pleura is damaged at the operation, air will enter the pleural cavity although the anæsthetist can sometimes prevent this by increasing the pressure of the anæsthetic gases. If the opening in the parietal pleura is not completely sealed by ligature or suture at the time of operation the blood-stained fluid which subsequently collects in the subscapular space will seep through into the pleural space. Whenever air or blood-stained fluid has been allowed to enter the pleural cavity, this should be aspirated within 24 hours of operation and the aspiration repeated if necessary so that the pleural space is kept empty.

Thoracoplasty with Plombage

The standard thoracoplasty (p. 406) has the following disadvantages:—(1) The operation is followed by considerable paradoxical movement which makes expectoration difficult and consequently there is an appreciable incidence of post-operative collapse and inhalation spread of the disease; (2) the operation has to be divided into stages in order to avoid excessive paradoxical movement; (3) there is a moderate amount of permanent deformity; (4) post-operative pain is often quite severe; and (5) the severity of the operation makes it unsuitable for many bilateral or unstable cases.

None of these objections applies to extrapleural pneumonolysis, but this operation is unsuitable for chronic disease due to the high incidence of subsequent tuberculous infection of the extrapleural space. In order to avoid the disadvantages of both thoracoplasty and extrapleural pneumothorax, Cleland recommended an operation in which the periosteum is separated from the ribs and an apicolysis performed in a manner similar to that employed in ordinary thoracoplasty but *the ribs are not removed.* A space is thus created between the denuded ribs and the lung which is covered by the intercostal tissues and the periosteum of the ribs: this space is filled with some inert plastic material such as " polythene " spheres or " polystan " sponge. This operation, which is done in one stage, does not give rise to appreciable paradoxical movement and there is no visible deformity: compared with thoracoplasty it is a less severe operation and is not followed by so much pain. Further, the reported incidence of tuberculous infection in the space occupied by the plastic material is far less than that associated with extrapleural pneumothorax, but the operation has not been practised for sufficiently long to justify a final assessment of the incidence of late complications.

In a number of centres this operation has completely replaced thoracoplasty, but in the author's opinion this practice is not yet justified as the late results are still unknown.

It is therefore suggested that thoracoplasty with plombage should only be used in preference to ordinary thoracoplasty under the following circumstances.—

(1) When the disease is bilateral and cavity closure would necessitate a two-stage thoracoplasty on each side.

(2) When the function of the contralateral lung is deficient due, for example, to the presence of an artificial pneumothorax or generalized pleural fibrosis.

(3) When there is disease of doubtful stability in the opposite lung or in the base of the homolateral lung.

(4) When the cardio-respiratory reserve is sufficiently impaired to make thoracoplasty dangerous, e.g. in patients with emphysema or generalized bronchospasm.

The operation.—The pre-operative preparation, anæsthesia and position on the table are the same as for ordinary thoracoplasty. The incision is exactly similar to that used for a first-stage thoracoplasty (p. 409). When the muscles have been divided the assistant elevates the scapula and the second and third digitations of serratus anterior are divided at their costal origin. The extent to which the lung is freed from the ribs depends upon the extent of the disease: as a general guide the separation from the ribs should be extended down to include the posterior portions of two ribs below the lowermost limit of any cavitation present, as in ordinary thoracoplasty. Starting with the lowest rib from which the lung is to be freed, the periosteum is incised along the upper and lower borders with the diathermy needle. the incisions are carried from the tip of the corresponding transverse process as far forwards as it is desired to mobilize the lung. The length of rib to be freed from its inner coat of periosteum is graded in a manner such that progressively larger fractions of the total length of each rib are isolated from below upwards, thus the periosteum of relatively small portions of the lower ribs is incised whereas the periosteum over the whole length of the second and often the third rib should be divided. After incising the periosteum, it is freed from the two borders and the inner surface of each rib with rugines. The lung covered by the intercostal muscles and strips of costal periosteum thus falls away from the ribs so that the latter resemble the wires of a bird-cage: each rib is still covered on its outer surface with periosteum which is supposed to help in the maintainance of an adequate blood supply to the rib. On reaching the first rib the periosteum is incised along the outer border and then separated from the inferior surface with a rugine. With the use of retractors the assistants separate the second rib from the third sufficiently to work inside the "bird-cage". There are usually one or more tears in the periosteum of the first rib along the inner border which can be extended backwards and forwards so that the inferior layer of periosteum can be drawn away from the first rib. Working between the ribs the apex of the lung covered by the parietal pleura is freed from its attachments to the cervical cupola and an apicolysis with posterior division of the upper intercostal bundles performed as in ordinary thoracoplasty. Although the access between the ribs is rather limited the apicolysis can be done without division of any ribs.

When the mobilization has been completed the space is filled with the selected plastic material: if polythene spheres are used these can be passed between the ribs if the latter are separated with retractors; between 24 and 30 are required for the equivalent of a 7-rib thoracoplasty, depending on the size of the patient. The space should not be packed tightly as this may lead to compression of the mediastinum or even pressure necrosis. Before closing, a half-inch incision is made through the skin in the mid-axillary line and a long hæmostatic forceps insinuated through this into the space: the forceps is used to grasp a long rubber drainage tube, one end of which is withdrawn through the axillary wound; the other end is left

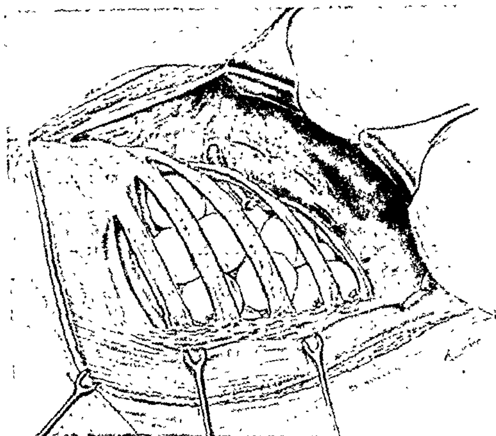


Fig 148.—Thoracoplasty with plombage.

A six-rib thoracoplasty (the first rib is not visible) has been completed and the space filled with polythene spheres

projecting between the ribs into the space for a distance of about two inches (Fig 148) The incision is then closed as in ordinary thoracoplasty and the axillary drainage tube connected to a water-seal bottle The dressings are fixed in position with elastoplast: there is no indication for tight strapping to control paradoxical movement as the latter does not occur.

Post-operative care.—Care after operation is similar to that for ordinary thoracoplasty except for the *management of the effusion which occurs* into the space. The rubber tube is used to drain the space into a water-seal bottle for 24–48 hours depending upon the amount of drainage: it is then withdrawn and the small axillary wound sutured. Subsequently it is

exceptional for fluid to collect in excess but the patient should be carefully observed during the first week for evidence of such excess: venous distension in the neck, an irritating cough, a feeling of severe constriction on the side of operation or bulging of the wound may all be caused by too much fluid in the space and indicate the need for aspiration with a large bore needle which is preferably inserted between the wound and the vertebral border of the scapula.

Complications.—In general the early complications are similar to those of ordinary thoracoplasty (q.v.) but are less frequent. Tuberculous infection of the space occupied by the plomb seems to occur infrequently: when it does arise, the wound should be reopened, the denuded ribs removed and the plomb taken out, thus converting the collapse to an ordinary thoracoplasty. If this is done under cover of anti-tuberculous chemotherapy there is a fairly good chance of primary wound healing.

THE SURGICAL TREATMENT OF DIAPHRAGMATIC HERNIA

Strictly speaking protrusion of some of the abdominal viscera through the diaphragm into the thorax should be described as a hernia only if there is a peritoneal sac, but the term is used here to include any such protrusion with or without a sac.

In order to consider the surgical treatment, it is necessary to divide diaphragmatic hernias into certain groups: from the purely operative point of view it is convenient to classify them as follows:—

(1) Hernias through the œsophageal hiatus.
(2) Hernias through the hiatus of Morgagni.
(3) Other types of diaphragmatic hernia.

Hernias through the œsophageal hiatus.—The œsophageal hiatus is the commonest site of hernia through the diaphragm and the condition is being recognized with increasing frequency. The indications for surgical treatment and the technique of operative repair can only be understood if this group is subdivided into the following types:—

(1) Para-œsophageal type.
(2) Sliding type.
(3) Combined para-œsophageal and sliding type.
(4) Congenital short œsophagus.

In the para-œsophageal type the œsophago-gastric junction remains below the diaphragm and the fundus of the stomach enclosed by a peritoneal sac rolls up in front of the œsophagus into the posterior mediastinum. The condition may progress until the whole stomach lies in the mediastinum behind the heart. exceptionally a part of the transverse colon may be drawn up by the omentum into the sac. As the œsophago-gastric junction remains a fixed point around which the greater curvature rotates into the chest, it is clear that, in those cases where the whole stomach enters the chest, the viscus will be " upside down ", that is, the greater curvature will be uppermost. Further, as the cardia remains within the abdomen and the œsophagus still forms

an acute angle with the fundus of the stomach, there is no reflux of gastric contents into the œsophagus and therefore no œsophagitis.

The indications for surgical treatment include:—(1) Retrosternal or upper abdominal pain due to gaseous distension of the thoracic portion of the stomach, (2) vomiting, (3) flatulence which is difficult to relieve by belching, (4) dyspnœa or palpitations due to pressure on the heart by the distended thoracic portion of the stomach, (5) symptoms of gastric obstruction and (6) hæmorrhage from gastric ulceration at the site of constriction at the hernial orifice. In fact as it is probable that most para-œsophageal hernias gradually increase in size surgical repair may be recommended unless the hernia is small and symptomless or the patient is unfit for operation.

The sliding hiatal hernia is a much more difficult surgical problem. In this condition the œsophago-gastric junction precedes the rest of the stomach into the chest so that it forms the apex of the hernia: in some cases there is only a very small pouch of stomach above the diaphragm; in larger hernias the radiological appearances after the ingestion of barium emulsion resemble the old-fashioned school bell, the œsophagus forming the handle and the cardiac end of the stomach representing the bell itself. The importance of this type of hernia is that the cardia ceases to be competent so that gastric contents have access to the œsophagus particularly when the patient is recumbent or stoops down: this leads to inflammation and ulceration of the lower end of the œsophagus ("reflux œsophagitis")* and, later, to shortening and stenosis of the œsophagus due to inflammatory fibrosis. Prior to these fibrotic changes, most authorities maintain that the œsophagus is not actually shortened although it may appear so from the radiological appearances as a result of elastic recoil and contraction of the longitudinal muscles. Reflux œsophagitis gives rise to pain, most commonly felt behind the lower end of the sternum, and often to persistent bleeding from the inflamed and ulcerated mucosa.

The incidence of recurrence following herniotomy for a sliding hernia is relatively high: in some reports such as that of Gertz and his colleagues,† a very high rate of recurrence has been found. This must be kept in mind when considering the surgical treatment.

Sliding hiatal hernias are seen most commonly in two widely different age groups:—(*a*) in infants and children and (*b*) in later life, usually after the age of 50 and most frequently in females with a tendency to obesity. It is probably wise to operate on the children as early as possible before œsophagitis has led to such fibrosis and shrinkage of the wall that reduction of the hernia becomes difficult or impossible. In adults, surgical treatment should be recommended only for those who fail to respond to medical measures. On the other hand, those with symptoms due to cicatricial stenosis of the œsophagus are not amenable to treatment by herniotomy as the cardia cannot be replaced below the diaphragm. In these cases surgery must be directed towards

* Allison, P. R., 1951, *Surg. Gynec. Obst.*, xcii, 419

† Gertz, T. C., Regout, J. E. P. M., and Thomsen, G., 1951, *Thorax*, vi, 316

the œsophageal lesion as such and not to the hernia (*see* Operations on the Œsophagus, Vol. II, Chap. XXXII).

Exceptionally a para-œsophageal hernia is combined with an upward slide of the œsophago-gastric junction: from the operative view-point this may be considered simply as a sliding hernia.

Congenital short œsophagus in which the œsophagus is anatomically short is now thought to be rare.* It is not amenable to herniotomy as the œsophagus cannot be lengthened sufficiently to place the cardia below the diaphragm. Unfortunately it may not be possible to distinguish this condition from a sliding hernia without operative exploration.

Operative treatment of hiatal hernia is directed towards reduction of the abdominal viscera back into the abdomen, obliteration or removal of the hernial sac and repair of the hiatus so as to prevent recurrence. This operation is well tolerated even by elderly individuals but, if the patient is considered a poor operative risk, and medical measures have failed to give relief, it may be justifiable to perform a left phrenic crush in the neck (p. 397) as this occasionally eases the symptoms: if it does so, the diaphragmatic paralysis may subsequently be made permanent but this should never be done if there is any *chance of a later attempt at herniotomy as it leads to complete degeneration* of the muscle of the diaphragm. It is appropriate to mention here that it is the fibres of the right crus which decussate to allow the œsophagus passage into the abdomen so that constriction of the hiatus will not be relieved by paralysing the left half of the diaphragm.

Preparation for herniotomy.—In patients who have bled from ulceration of the stomach or œsophagus, blood transfusion may be required in addition to iron therapy in order to correct anæmia. Œsophagoscopy is advisable in sliding hernias in order to examine the lower end of the œsophagus for evidence of œsophagitis and loss of mobility due to fibrosis. It is assumed that all cases have been examined radiologically in detail so that the exact nature of the hernia is known. In cases of obstruction, a rubber œsophageal tube should be passed. This will at least empty any pouch of the stomach which may exist proximal to the obstruction and further, in many cases it is possible to manipulate the tube subsequently into the obstructed herniated part of the stomach and thus relieve the tension within the viscus; this sometimes releases the obstruction to the outflow from the stomach into the duodenum so that the patient may be completely relieved of the obstruction prior to operation. This is highly desirable as patients submitted to surgery in the presence of obstruction are very liable to develop serious and even fatal post-operative ileus

* Barrett, N R, 1952, *Proc Roy Soc Med.*, xlv, 279

† Harrington, S W, 1948, *Surg Gynec and Obst*, lxxxvi, 735.

treatment of hiatal hernias than anyone else and reports a very low … Nevertheless most … operate through the …ageal hiatus and the cardia are thus exposed to direct vision and adhesions may be easily

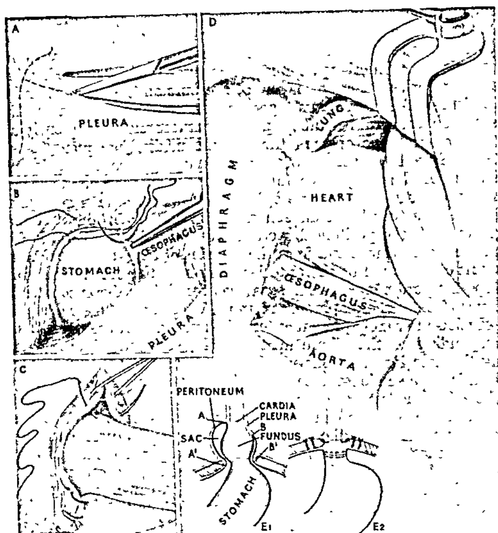


Fig. 149.—Surgical repair of hiatus hernia.

divided; further, when necessary, the œsophagus can be freed a long way up in the chest in order to give it greater length so as to enable the cardia to be brought below the diaphragm. For these reasons only the thoracic approach will be described here.

* Allison, P. R., 1951, *Surg Gynec and Obst.*, xcii, 419.
† Sweet, R. H., 1952, *Ann Surg*, cxxxv, 1.

A postero-lateral thoracotomy (p. 453) is performed under general anæsthesia through the bed of the eighth rib which should be removed from the tip of the transverse process forwards to the costo-chondral junction. In children it is preferable to open the chest through the eighth intercostal space. The approach should always be from the left side even when the hernial sac is larger on the right—a not uncommon finding in the para-œsophageal type—for the œsophageal hiatus cannot be exposed properly from the right side.

The lung is retracted upwards and the pulmonary ligament divided almost up to the inferior pulmonary vein (Fig. 149). The mediastinum is entered between the two layers of the pulmonary ligament and the lower end of the œsophagus together with the vagi is freed by blunt dissection; a soft rubber tube is passed round it and subsequently used for retraction. The opening through the mediastinal pleura is now extended from the lower end of the pulmonary ligament forwards across the front of the œsophageal hiatus and backwards and downwards behind the hiatus so as to expose the muscle fibres of the diaphragmatic crura. By further blunt dissection the herniated portion of stomach together with the peritoneal sac and overlying fascial tissue is freed from the mediastinum and from the margins of the œsophageal hiatus. By gentle retraction of the anterior margin of the hiatus with tissue forceps the peritoneum can be separated for a short distance from the under surface of the diaphragm in front, laterally and medially. The sac which is invariably present anteriorly (but may be absent posteriorly corresponding to the "bare area" of the stomach) is now opened along the margins of the hiatus, thus leaving a fringe which has been cleared from the under surface of the diaphragm; by passing two fingers of the left hand into the sac the peritoneum covering the herniated portion of the stomach can be cut away so as to leave a fringe about ½ in. long attached to the cardia. This fringe is sutured with interrupted silk sutures to the free border of the peritoneum which was freed from the margins of the hiatus (Fig. 149B). This serves to draw the cardia into the abdomen so that attention can now be given to repairing the hiatus above the œsophagogastric junction. The margins of the hiatus in front and on the two sides have already been cleared; by drawing the cardia forwards, the crural muscle fibres forming the margins of the hiatus posteriorly can be exposed and freed from areolar tissue and fat. At this stage it is convenient if the anæsthetist

lumen of the œsophagus is narrowed. The muscle fibres are then drawn together behind the cardia with interrupted silk sutures, being careful not to tie the sutures so tightly that the muscle fibres are strangulated. One or two sutures may also be placed through the margins of the hiatus in front of the œsophagus The two sutures placed nearest the œsophagus, one in front and one behind, should include the fascia covering the œsophagus together with a few of the longitudinal muscle fibres (Fig. 149C). When the margins of the

hiatus have been approximated it should still be possible to pass the tip of the finger into the hiatus alongside the œsophagus; if the opening is narrowed more than this, the patient is liable to suffer from dysphagia following the operation.

Some surgeons recommend that the left phrenic nerve should be crushed in order to elevate the left half of the diaphragm; this may be advisable if there has been difficulty in reducing the cardia below the diaphragm but in other cases it is preferable to leave the nerve supply intact in order to avoid degeneration of the muscle. Finally the thoracotomy incision is closed after inserting a basal intercostal drain which is connected to a water-seal bottle. The tube passed by the anæsthetist into the stomach should be left *in situ*, particularly in cases where there has been obstruction, so that the stomach may be kept empty by suction during the early post-operative period.

As the incidence of recurrence following this type of operation has been considerable when performed for a sliding hernia, and as œsophageal reflux occasionally persists in spite of continued reduction of the hernia, several surgeons have modified the operation in the case of sliding hernias. Mason (1947)* recommends making a radical counter incision in the posterior part of the dome of the diaphragm so that the hiatus is approached from the abdominal aspect and reduction and repair effected from below the diaphragm. The hernial contents are freed from the sac and a rubber catheter is passed through the counter incision and then round the œsophago-gastric junction so that it can be drawn downwards and forwards until at least 1 in. of the œsophagus is below the diaphragm. The margins of the hiatus lying behind the œsophagus are approximated with interrupted sutures of No. 40 linen thread and the œsophagus is anchored to the reconstituted hiatus with a few stitches. The counter incision in the diaphragm is then closed. Allison (1951) recommends that the counter incision should be used for suturing the cut edge of peritoneum and fascia around the cardia to the under surface of the diaphragm; the repair of the hiatus is subsequently done from the thoracic side. Gertz and his colleagues (1951) advise that this counter incision should also be used for suturing the fundus of the stomach to the subdiaphragmati[illegible] the œsophagus over an area of 2–3 cm. so [illegible] these two organs is reconstructed, thus diminishing the likelihood of continued œsophageal reflux.

Merendino, Varco and Wangensteen (1949)† favour an entirely different technique for sliding hernias, in which it is difficult to elongate the œsophagus sufficiently to reduce the hernia without tension. The left phrenic nerve is divided so as to provide permanent paralysis of the hemidiaphragm. A site for a "new" hiatus is chosen in the postero-medial part of the dome of the diaphragm and an opening made in this position: the diaphragm is divided between this opening and the œsophageal hiatus so that the œsophagus may be displaced

* Quoted by Evans, C. J., and Simpson, J. A., 1950, *Thorax*, v, 343

† Merendino, K. A., Varco, R. L., and Wangensteen, O. H., 1949, *Ann Surg*, cxxix, 185.

forwards into the new site. The tendinous margins of this "new" hiatus are sutured to the terminal œsophagus and the "old" hiatus is closed by approximation of the crura.

Post-operative care.—The stomach is kept empty by intermittent aspiration through the gastric tube: this is important as gastric retention due to temporary damage to the vagi during operation is not uncommon. When the quantity of fluid obtained by aspiration is small, the tube may be removed, provided the bowel sounds have returned. During this period of gastric suction the patient must receive adequate quantities of fluid and salt by intravenous infusion. The intercostal drain is removed at the end of 24 hours provided the quantity of drainage is small and an X-ray film has confirmed complete re-expansion of the lung.

Hernias through the hiatus of Morgagni.—The hiatus of Morgagni is the space between the sternal and costal fibres of the diaphragm through which the superior epigastric vessels enter the abdominal wall. It is the least common site for herniation through the diaphragm and only justifies separate consideration because the method of operative repair is totally different from that employed for other types. It is a congenital hernia with a complete peritoneal sac which usually contains a portion of the transverse colon together with omentum but it may contain only omentum: in the latter case the X-ray appearances may be erroneously diagnosed as showing an anterior mediastinal tumour. The hernia extends upwards behind the sternum and in front of the heart, often more to the right than the left, and is frequently large in size. Although the neck of the sac is said to be bounded by the margins of the hiatus, it is common to find complete absence of the sternal fibres of the diaphragm so that it would be more accurate to describe these hernias as retrosternal.

Unless the patient is unfit for operation, all cases in which the sac contains large bowel should be submitted to operation, as obstruction is liable to occur sooner or later: in addition cardiac function may be embarrassed due to compression from in front.

Operative technique.—Operation is performed under general anæsthesia with the patient lying on his back. A right paramedian incision is made from the costoxiphoid angle down to a point just above the umbilicus. The abdomen is opened medial to the falciform ligament. The omentum and colon in the sac are then drawn down through the hernial orifice into the abdomen. The peritoneum is divided along the margins of the hernial orifice and traction applied to the sac so that this can be gradually freed from its thoracic attachments and finally removed: it is preferable if this can be done without opening either pleural cavity. The margins of the hernial orifice are approximated from side to side with interrupted silk stitches. The diaphragmatic fibres will be found to be continuous with the posterior rectus sheath so that the suture of this layer may be continued until the abdominal cavity is closed. It is advisable to draw this suture

line forwards with a few interrupted sutures so that it is attached to the costal margin and xiphisternum. Finally the rest of the abdominal wound is closed in layers.

In many cases exposure through an incision limited to the abdomen is inadequate to allow safe reduction of the hernial contents because of adhesions and it may also be difficult or impossible to remove the hernial sac through this limited exposure. In such circumstances the lower part of the sternum should be divided in the mid-line with Lubitch's shears up to the level of the third or fourth space: here the sternum is divided horizontally so that the two halves may be retracted forcibly with a self-retaining retractor. This provides excellent exposure and the sternum can be readily repaired before closing by interrupted wire sutures passing right through its substance.

Other types of diaphragmatic hernia.—When considering operative treatment, all types of diaphragmatic hernia other than those occurring through the œsophageal hiatus or the hiatus of Morgagni may be grouped together for convenience as the basic steps in the operation are similar for all cases.

No special pre-operative preparation is required unless there is obstruction present: this should be treated in the manner described for hiatal hernias (*see* p. 424).

The chest is opened under general anæsthesia by a postero-lateral incision, through the eighth rib bed in adults or the eighth intercostal space in children, on the side of the hernia. In most cases there is no hernial sac and the abdominal viscera are found in the pleural cavity producing a varying amount of collapse of the lung. The herniated viscera may be very adherent to the intrathoracic structures, particularly when operation is performed for traumatic hernias some long time after the original injury; in other cases there may be no adhesions at all. These adhesions must all be divided so that the viscera are free to be replaced in the abdomen. The adhesions are liable to be particularly dense around the margins of the hernial orifice, especially if there have been attacks of subacute obstruction, and great care should be taken to avoid damaging the bowel when freeing these. If there are adhesions between the abdominal viscera and the under surface of the diaphragm in the neighbourhood of the hernial orifice, these must also be separated If this proves difficult, the hernial orifice should be enlarged by incising the diaphragm. The herniated viscera must now be reduced into the abdomen and kept there while the opening in the diaphragm is repaired. With large herniæ, particularly those of congenital origin, there may be difficulty in reducing the hernial contents because the abdominal cavity seems too small to receive them. For this reason some surgeons prefer an abdominal approach when difficulty is anticipated so that the abdominal wall may be stretched manually or the rectus muscles divided (Ladd and Gross, 1941*), but this is quite unnecessary if

* Ladd, W. E., and Gross, R. E. (1941). "Abdominal Surgery of Infancy and Childhood." Philadelphia, W. B. Saunders Co.

the anæsthetist makes proper use of muscle relaxants. The abdominal viscera should be gradually replaced in the abdomen with a moist swab held in sponge-holding forceps while the assistant retracts the margins of the hernial orifice upwards with tissue forceps. When reduction is finally completed it is convenient to maintain reduction with a moistened hemmed swab made of several thicknesses of aertex material. The margins of the hernial orifice are brought into apposition and overlapped with two rows of interrupted thick silk or thread sutures, the aertex swab being removed from the abdomen before completing the closure. The anæsthetist now inflates the lung and the chest is closed in layers after the insertion of a basal water-seal drain. The phrenic nerve should not be crushed as there is no evidence that diaphragmatic paralysis promotes union of the sutured margins of the hernial orifice.

In those cases in which there is a hernial sac present, there is no basic difference in the operation except that, after opening the chest, the sac is freed from adhesions to the thoracic viscera and then opened widely. The contents are freed from the sac and from the under surface of the diaphragm in the region of the hernial orifice and reduced into the abdomen. The neck of the sac is obliterated with interrupted mattress sutures and the sac is then excised. The hernial orifice is closed in the manner described above.

Special difficulties in closing the hernial orifice.—Obliteration of the hernial orifice rarely gives rise to difficulty, even when large, unless the aperture is bounded on one side by the chest wall: this is not an uncommon finding with large congenital defects in the paravertebral gutter (the region of the pleuroperitoneal hiatus) and with some hernias resulting from indirect trauma. The difficulty can usually be overcome by approximating the free border of the diaphragm to the intercostal tissues of the chest wall with interrupted mattress sutures. If the deficiency is situated anterolaterally the skin and subcutaneous tissues may be raised as a flap by undercutting from the original thoracotomy incision so that mattress sutures passing through the free border of the diaphragm can be brought right through the chest wall and tied externally. If the deficiency extends as far as the vertebral column the diaphragm may be sutured to the anterior longitudinal ligament and the prevertebral fascia. If the diaphragm is obviously under tension when the hernial orifice has been closed, this may sometimes be relieved by incising the dome of the diaphragm at right angles to the line of tension and closing this defect in the line of tension. Very rarely it may be necessary to remove some of the lower ribs subperiosteally so that the chest wall may be drawn in to meet the diaphragmatic margin of the defect.

Indications for surgical treatment.—Consideration of the indications for surgical treatment necessitates subdividing this varied group of hernias according to their etiology.

(1) Hernias due to penetrating wounds.

If the patient is seen shortly after receiving a penetrating wound, operation should be undertaken as soon as the effects of shock and hæmorrhage have been adequately treated as recognizable herniation through the diaphragm is likely to be complicated by damage to the abdominal viscera. The only exception to this rule applies to penetrating wounds on the right side in which there is good evidence that the injury and herniation are confined to a small part of the liver. When a patient is seen for the first time after an interval following the injury, operation should be recommended at an early date as the hernia is likely to increase in size and there is always the risk of obstruction or strangulation.

(2) Hernias due to crushing injuries.

Operation may be delayed until the patient has fully recovered from the injury unless (*a*) there is evidence of rupture or serious contusion of the viscera, or (*b*) there is marked respiratory distress with cyanosis and tachycardia as these symptoms of gross cardio-respiratory disturbance are prone to continue until the hernia has been reduced. Patients seen at a later date should all be treated surgically unless the general condition makes the procedure dangerous.

(3) Hernias due to inflammatory necrosis, e.g. secondary to a subphrenic abscess.

Radical operation is indicated as soon as the infective process has entirely subsided unless the herniation is limited to a portion of liver.

(4) Congenital hernias.

There is general agreement that all the varieties should be submitted to herniotomy sooner or later but it is difficult to decide at what age to recommend operation in those cases diagnosed in infancy. In newly-born infants with massive hernias it is probably wise to operate as soon as possible so that the thoracic organs may occupy their normal positions: experience with the operative treatment of congenital atresia of the œsophagus has shown that such early operations are not so dangerous as previously supposed. In the case of smaller hernias it may be preferable to wait until the child is well stabilized after weaning provided the child remains free from any symptoms suggesting partial obstruction.

Post-operative care.—This is the same as that described for hiatal hernias (p 428).

CHAPTER VIII

OPERATIONS ON THE SPINAL CORD

By LAMBERT ROGERS, V.R.D.

LYING in the sagittal plane near the centre of axis of rotation of the vertebral bodies and covered posteriorly by the bony neural arches and their overlying powerful muscle masses, the relatively small spinal cord is beautifully protected from injury during movements of the body.

The cord, however, is otherwise highly vulnerable inasmuch as it represents, as it were, a "bottle neck" of concentrated nervous pathways leading from the relatively massive brain to the extensive periphery, so that a comparatively trivial injury to it, or its blood supply, whether produced by external violence or by pressure from a neoplasm or inflammatory lesion, may result in widespread paralysis. Furthermore, there is no regeneration of divided pathways in the human cord and thus it follows that, from the nature of its protection, injuries of the spinal cord produced by violence are, fortunately, relatively uncommon, but when they do occur are likely to be both catastrophic in type and disastrous in effect.

ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

Surgical anatomy. Landmarks of the spine.—The tips of the spinous processes may readily be identified by palpation ; the most prominent is that of the 1st thoracic vertebra, but the uppermost spine to form a

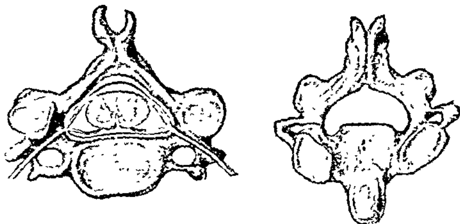


Fig. 150.—Cervical vertebra from above with cord in situ, and axis from above showing facets in front of the neural grooves.

visible projection is usually the 7th cervical (so called "vertebra prominens"), except when the neck is flexed, when the 6th cervical spine may come to the surface. The root of the spine of the scapula

normally lies opposite the 3rd thoracic spinous process while its inferior angle is at the level of the 7th thoracic spine. The highest part of the iliac crest constitutes a very constant landmark, being on a level with the upper edge of the 4th lumbar spine or the space between this and the next spine above.

Vertebral column.—In the *cervical* region the spinal canal is relatively wide and there is a considerable space between the cord and its bony surroundings. The cervical vertebræ are characterized by the presence

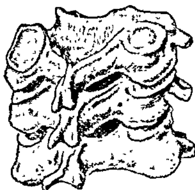


Fig. 151.—Cervical vertebræ from behind.

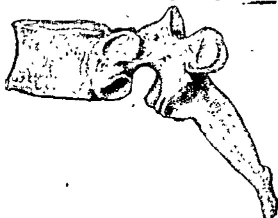


Fig. 152.—Thoracic vertebra from side.

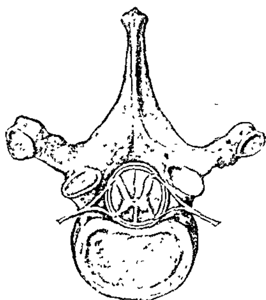


Fig. 153.—Thoracic vertebra from above with cord *in situ*

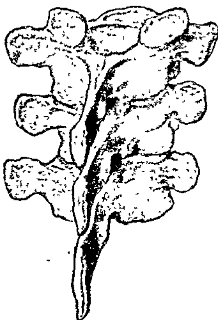


Fig. 154.—Thoracic vertebræ from behind.

of the foramen for the vertebral artery and its accompanying vein and sympathetic nerve fibres. This artery represents a preneural, post-costal anastomosis (T. Yeates) and thus lies in front of the issuing nerves. The typical spinous processes are bifid. This is the most mobile part of the column ... horizontal. Tl

front of the neural grooves but in the remainder of the cervical vertebræ are placed behind them. (Figs. 150, 151.)

In the *thoracic* region the spinal canal is relatively narrower, so that there is less space between the cord, *enclosed in its meninges*, and its bony surroundings; the laminæ are relatively broader than in the cervical region and more closely approximated to each other, and the spinous processes are long and obliquely placed. The articular processes lie in a plane which is almost vertical, and the upper ones look backwards and outwards. Because of the dorsal convexity of the spinal column in this region and the fact that here the post-vertebral grooves

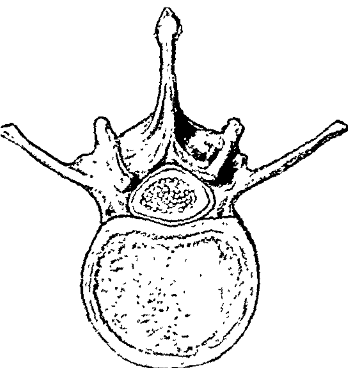


Fig. 155.—Lumbar vertebra from above, with cauda equina *in situ*.



Fig. 156.—Lumbar vertebræ from behind.

are relatively shallow and the erector spinæ muscle mass is flattened and tendinous, this part of the spinal canal is the most readily accessible *to the surgeon. (Figs. 152, 153, 154.)*

In the *lumbar* region the spinal canal again becomes relatively large in comparison with the space taken up by *the cord and its membranous* coverings, while the individual vertebræ are altogether more massive and the vertebral grooves deeper, owing to the greater development *of the erector spinæ muscle mass.* The spinous processes are stout and project almost horizontally backwards, in contra-distinction to the *obliquely-placed spines of the cervical* and thoracic vertebræ. The articular processes are vertically placed, and the upper ones look inwards and firmly interlock with the *inferior* facets of the vertebra above, so that little or no rotary *motion* is possible in this part of the column. This part of the spinal canal is the most deeply placed and *least accessible. (Figs. 155, 156.)*

The intervertebral discs.—These consist of upper and lower plates of cartilage with the annulus fibrosus and the nucleus pulposus (remains of notochord). The discs give mobility to the spinal column without impairing its strength. If either cartilage plate is damaged or the annulus fractured, a herniation of nuclear material may take place. This extrusion of disc substance may give rise to symptoms.* (See p. 463.)

Spinal meninges.—The spinal *dura mater* is a fibrous tube which extends from the edge of the foramen magnum to the second sacral vertebra. It contrasts with the corresponding cranial membrane in being much less intimately related either to its bony surroundings or to its neural contents, since posteriorly it is separated from the neural arches by an *epidural* space, while it forms but a loose sac around the cord. Below the level of the foramen magnum the dural tube is unattached posteriorly. It is attached to the bone around the foramen magnum and, by means of the filum terminale, to the back of the coccyx with which it fuses where it is closed below; elsewhere the dura is loosely adherent anteriorly to the posterior longitudinal ligament, and the anterior and posterior nerve roots carry with them tubular prolongations which blend with the periosteum at the margins of the intervertebral foramina. Because of its close relationship with the backs of the bodies of the ve[illegible] e of rotation of the column, [illegible] posteriorly, the dural tube [illegible] ıost freedom from interference by movements taking place in the vertebral column. The healthy spinal dura is a bluish pulsating tube covered posteriorly by a thin layer of pale epidural fat.

The *spinal arachnoid* is directly continuous with that within the cranial cavity and is a filmy and transparent membrane. If the dura is carefully opened so as not to damage the arachnoid, the cord, bathed with cerebro-spinal fluid, may be seen through it. Filmy strands connect the arachnoid with the pia. Small white calcareous or bony plaques occur not infrequently in the spinal arachnoid. Like the dura, it gives a sheath to the issuing nerve roots.

The *subarachnoid space*, containing the cerebro-spinal fluid, is continuous above with the cerebro-spinal fluid reservoirs within the skull and is closed below at the level of the upper border of the 2nd sacral vertebra. The cord itself terminates as the conus medullaris (terminalis), below which is a large pool of cerebro-spinal fluid (lumbar pond) which bathes the cauda equina and the filum terminale. It is this pond of cerebro-spinal fluid which is tapped when lumbar puncture is performed (Fig. 157). In the adult the conus lies at the lower border of the 1st lumbar vertebra, but in early fœtal life the cord occupies

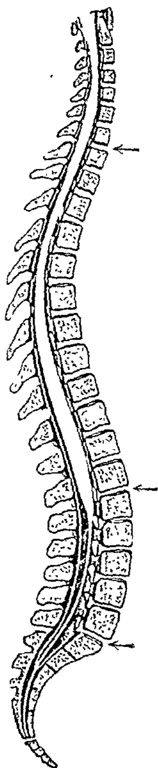


Fig. 157.—Extent of dura, arachnoid, and cord.

Fig. 158.—Ligamentum denticulatum and fork. (*After Elsberg.*)

the whole spinal canal and at birth extends as low as the 3rd lumbar vertebra. *It is important to realize this lest the conus medullaris be damaged when lumbar puncture is performed on an infant.*

The *pia* over the spinal cord is thicker and stronger than the corresponding membrane of the brain. It is beset with fine vessels, and sends septa into the anterior fissure and the posterior median sulcus of the cord Anteriorly it thickens to form a glistening band (linea splendens), which is continuous below with the filum terminale.

The *ligamentum denticulatum* attaches the cord to the dural tube. It consists on either side of 20-22 triangular slips which lie between the anterior and posterior nerve-roots and pass from the pia to the dura, to which each slip is attached by its apex midway between the openings in the dura for the passage of the individual nerves. (Fig. 158.) The lowest denticulation is fork-shaped instead of triangular, and is crossed by the first lumbar nerve.*†

The spinal cord.—Somewhat flattened anteroposteriorly in the cervical region, the cord elsewhere has a circular cross-section. As the issuing nerves are given off from it, the amount of white matter which it contains decreases, so that this is relatively less in amount in the lower than in the upper parts of the cord. (Fig. 159.) The cord extends from the margin of the foramen magnum to its conical termination at the level of the lower border of the 1st lumbar vertebra, and presents expansions (cervical and lumbar enlargements) at the sites of origin of the limb-plexuses.

The *cervical enlargement* occupies the upper part of the cord and extends down to the 2nd thoracic vertebra, attaining its maximum girth at the level of the 5th or 6th cervical vertebra. The *lumbar enlargement* begins at the level of the 10th thoracic vertebra and attains its maximum development opposite the 12th, and below this rapidly tapers into the conus medullaris.

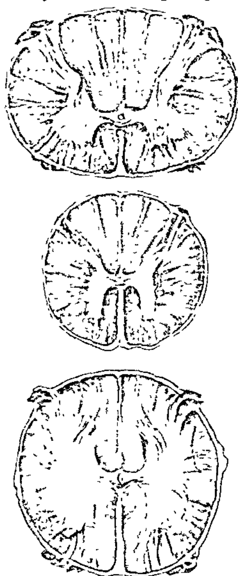


Fig. 159.—Transverse section of cord at cervical, dorsal, and lumbar levels.

* Elsberg, "Diseases of the Spinal Cord and its Membranes," N Y., 1916.
† E. Kahn has recently drawn attention to the role of the dentate ligaments in cord compression *Univ. Hosp. Bull., Ann. Arbor.*, 1947, xiii, 1.

The level of particular segments within the cord.—The cord being shorter than the spinal canal, the segmental nerves have an oblique intraspinal course between their origins and the intervertebral foramina through which they leave the canal. The length of the intraspinal course of the nerves progressively increases from above downwards (Fig. 160). Although there is a certain amount of variation the following statements are sufficiently accurate to be of practical value.*

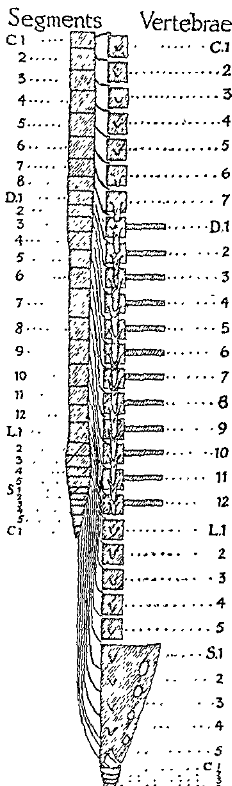


Fig. 160—Relation of vertebræ to segments.

(*a*) The intraspinal course increases fairly regularly for the cervical and thoracic nerves. It is about equal to the depth of one vertebra for the upper cervical and of two vertebræ for the lower cervical; of three vertebræ for the upper six thoracic and of four vertebræ for the lower six thoracic. (Thus the 10th thoracic segment would correspond with the 6th thoracic vertebra.)

(*b*) The origins of the lumbar nerves (segments) are opposite the 10th and 11th thoracic spines.

(*c*) The origins of the sacral nerves (segments) are opposite the 12th thoracic spine and the interspinous ligament between it and the 1st lumbar spine.

The nominal relationship of nerves and vertebræ changes at the 8th cervical nerve; above this the nerve issues above the vertebra of the same name; below this level the nerve issues below the vertebra of the same name.

The nerve roots.—Each of the 31 pairs of spinal nerves arises from the side of the cord by two roots, anterior and posterior, of which the posterior root is the larger except in the case of the suboccipital nerve, the posterior root of which is sometimes absent. Both roots arise from the cord by

* Medical Research Council, Rept 11, "Injuries of the Spinal Cord and Cauda Equina," 1924.

fasciculi, but whereas those comprising the posterior roots enter the cord consecutively along a continuous straight line at the bottom of a slight furrow, those giving origin to the anterior roots arise somewhat irregularly from the antero-lateral surface of the cord and from an area of some breadth. (Fig. 161.) The ganglia, which lie upon the posterior roots just before their union with the anterior roots to form the issuing spinal nerves, for the most part occupy the intervertebral foramina. The spinal nerves leave the vertebral column in front of the articular processes except in the case of the first two cervical nerves which issue behind the articular masses (Fig. 150).

The filum terminale (central ligament) lies among the nerve roots comprising the cauda equina and may be distinguished from them by its silvery appearance. The central canal of the spinal cord usually extends into its upper end but for the most part it is comprised of connective tissue with some vessels and nerve fibres and is a specialized prolongation of the pia mater. At the second sacral vertebra the filum passes through the dura, receives an investment from it and is attached to the lower end of the sacral canal or to the back of the coccyx.

It may be unduly taut in some subjects and by its traction on the cord cause paraplegia which has been relieved by its division.*



Fig. 161.—The anterior and posterior nerve-roots.

Blood supply of meninges and cord. Arteries.—Spinal arteries enter the spinal canal through the interverte-bral foramina, and give off three sets of branches: (i) *prelaminar*, to the deep surface of the neural arches; (ii) *neural*, which pierce the dura immediately above the site of exit of the corresponding spinal nerve; and (iii) *postcentral*, which pass inwards to the back of the vertebral bodies and give off ascending and descending branches which anastomose with corresponding branches from the arteries above and below. In the cervical region the spinal arteries arise from the vertebral, in the thoracic and lumbar regions from the dorsal branches of the intercostal and lumbar arteries respectively. Twigs also enter the spinal canal in the cervical region from the ascending cervical branch of the inferior thyroid artery and in the sacral region from the lateral sacral artery. A large number of tortuous small arteries may be seen ramifying in the pial covering over

* The Filum Terminale Syndrome G. J. Garceau has reported three cases, two in boys aged 13 and one in a girl aged 15. In one the filum was large and so tense that when divided its ends separated by 1 cm (*J. Bone and Jt Surg.*, 1953, xxxv-A, 711).

the surface of the cord. These arise from five longitudinal trunks, one of which is the anteromedian (anterior spinal) artery while the other four are postero-laterally placed, lying in the sulci in which the posterior nerves roots enter the cord, and being related to the anterior and posterior aspects of the line of posterior roots. These longitudinal trunks are connected above with the anterior and posterior spinal branches of the vertebral artery and anastomose with the branches which enter with the nerve-roots.

Veins.—The veins of the cord are small, numerous and tortuous, but for the most part form longitudinal trunks which ramify on the anterior and posterior surfaces of the cord and in relation to each set of nerve-roots. The state of the veins which run longitudinally on the back of the cord is sometimes helpful to the surgeon in enabling him to decide whether a laminectomy is above or below a site of cord compression; the blood flow in these veins is upwards and so those below the site of compression are prominent and congested while those above appear normal. The veins of the spinal canal are large and complex in their arrangement, but for the most part form anterior and posterior plexuses related respectively to the backs of the vertebral bodies on either side of the posterior common ligament, and to the deep surfaces of the laminæ and ligamenta subflava. Wide channels pass through these ligaments to connect with dorsal spinal venous plexuses in the vertebral grooves. Branches also traverse the intervertebral foramina to join the posterior branches of the intercostal and lumbar veins. At the base of the skull the venous plexuses enter the basilar and occipital sinuses and give off branches which emerge above the neural arch of the atlas to form the origin of the vertebral vein. H. Kaydi (1889) and more recently T. H Suh and L. Alexander of Boston (1939)* have shown that there is a striking difference in size between the various radicular arteries and veins. The blood supply of the cord depends on from 6 to 8 anterior and from 5 to 8 posterior radicular arteries and from 6 to 11 anterior and 5 to 10 posterior radicular veins. The largest of each set of vessels are found in the lumbar region as the arteria radiculus magna and the vena radiculus magna. Every effort should be made to preserve the radicular vessels. Occasional instances in which section of a root has been followed by myelomalacia may have been due to the fact that the particular root divided has carried one of the main vessels. The middle thoracic part of the spinal cord has the poorest local segmental circulation.

Pressure on the abdomen causes congestion of the veins within the spinal canal which may be troublesome in certain operations, e.g. for intervertebral disc lesions. This congestion can be avoided by so arranging the patient on the operation table that the body weight is taken by the anterior iliac spines and not by the abdomen.

The cerebro-spinal fluid is formed by the choroid plexuses in the cerebral ventricles, and in normal subjects its total quantity is from

* *Arch. Neurol. and Psych.*, 1939, xli, 659.

110 to 150 c.c. Fluid produced by the plexuses of the lateral ventricles enters the 3rd ventricle through the foramen of Monro on each side, and is here added to by that produced by the plexus of this ventricle. It flows backwards through the Sylvian aqueduct into the 4th ventricle, where it is again added to by the plexus here and, in addition to filling the ventricle, occupies the central canal of the cord. Leaving the 4th ventricle through the large median foramen of Magendie and the laterally placed foramina of Luschka, it fills the basal cisterns and traverses the cranial and spinal subarachnoid spaces. It is absorbed by the arachnoidal villi into the intracranial venous sinuses. The production, passage and absorption of the fluid has been termed the third circulation (Harvey Cushing).

Spinal shock is the phase of depressed or suppressed reflex activity in that part of the cord suddenly isolated from the rest of the central nervous system. It is thought to be due to a sudden interruption of impulses passing down the cord and not to a general depression in vitality consequent upon the injury. This is supported by an observation of Gordon Holmes that in a unilateral lesion of the cord spinal shock may be confined to the injured side but the cause of this sudden and persistent state of depressed reflex activity, increasingly profound as we ascend the animal scale, has not really been satisfactorily explained. For a variable period (usually, however, between 2 and 4 days) the distal part of the cord is incapable of subserving even the simplest reflex; thus, following a high thoracic transection, there is complete flaccid paralysis below the level of the section, and retention of urine and fæces, but after spinal shock has passed off, reflexes return and retention is no longer complete; small quantities of urine may now be expelled and a reflex type of micturition come about, so that the bladder discharges itself at intervals.

The bladder.—This " automatic bladder " is an excellent example of how smooth muscle adapts itself to carry on its original functions after the loss of its extrinsic nerve supply. In its typical form it is seen after a complete cord lesion high in the thoracic region.* The fluid content sufficient to excite the local vesical emptying reflex varies within rather wide limits but is usually somewhere about 300 c.c. The automatic action may be hampered in cases in which the motor nerves (nervi erigentes, S.2, S.3, occasionally S.4) or their centres of origin have been damaged, while the hypogastric inhibitory nerves from the lumbar sympathetic ganglia are left intact. This may occur in crush or other injuries of the conus medullaris, when improvement may follow presacral sympathectomy which, by lessening sphincter tone and by withdrawal of the inhibitory impulses to the bladder muscular tone, assists the establishment of the automatic action. (*See* " Surgery of Sympathetic Nervous System ", Vol. II.) The usual course of the effects of a transverse lesion of the cord on micturition is first retention, then overflow incontinence and next the automatic

* J. Martin and Loyal Davis, *Annals Surg.*, 1947, cxxvi, 472.

bladder. Sepsis or pronounced debility may delay or prevent the appearance of this automaticity.

Care of the bladder in paraplegic cases.—Infection occurs much more readily in an over-distended bladder with a stretched musculature than in one in which muscle tonus has been maintained and the mucosa protected from the stretching which interferes with its blood supply. Distension, therefore, should be prevented either by frequent catheterization, by the use of an indwelling catheter, or by establishing a suprapubic cystostomy. When repeated catheterization is carried out this must be gently and carefully performed, because injury, however slight, like overstretching, is conducive to infection. An indwelling catheter with an apparatus to effect tidal drainage has proved effective. and chemotherapy is valuable (*see also* p. 484).

Conduction in the cord.—The position of the chief conducting tracts is shown in Fig. 162. Once transected, regeneration does not occur in

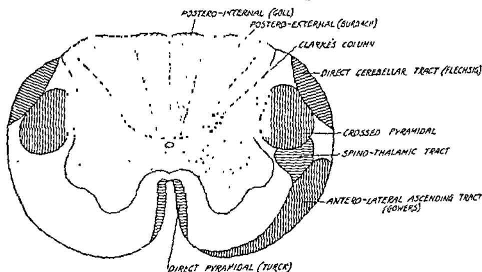


Fig. 162.—Transverse section of spinal cord, showing chief motor and sensory tracts.

the human cord and all attempts to suture divided cords have proved futile. As Pilcher* has graphically put it, "Like Humpty Dumpty, the spinal cord can never be put together again." Although regeneration occurs in fish and amphibians, e.g. the lopped off tail of the newt is reformed and with it the terminal part of its cord, in mammals there is no satisfactory evidence of regeneration either in fœtuses or adults.† Although when completely severed the cord lacks the power of regenerating, it may yet be compressed to a surprising extent and recover its function when the compression is relieved. This power of recovery is greatest in children and young adults (Wilfred Trotter) and is very dependent on the state of the blood supply. I have recorded a case in which the cord was so flattened by a tumour as to resemble a piece of tape, but the patient, a girl

* *South Surgeon*, 1942, ii, 755.
† See D. Hooker, *Journ Comp. Neurol.*, 1932, lxi, 277.

aged 16, who was completely paraplegic and incontinent at the time of removal of the tumour, had within four months fully recovered both sensation and motor power, as well as control of the sphincters.*

As a rule recovery after relief of compression is satisfactory in cases of spastic paraplegia in extension or even in flexion. It has been stated that once flaccid paralysis is complete no recovery may be expected but although the outlook is much less favourable in such cases it is not hopeless. I have had a case in a woman aged 42 who had flaccid paralysis and large pressure sores, complete loss of sensation and absent reflexes. The tumour, a neurinoma lying antero-lateral to the cord at the level of the 7th thoracic vertebra, was removed in August, 1944. She has made a complete recovery and has since married.

Elsberg† has pointed out that the more peripheral dermatomes are represented in the cord by tracts which lie external to those arising from more central dermatomes, and it is therefore sometimes possible to differentiate pressure from without the cord (e.g. extramedullary tumour) from pressure from within the cord (e.g. intramedullary tumour), since in the former case there is a progressive march of symptoms from the periphery towards the trunk, i.e. symptoms appear in the foot before the thigh.

PUNCTURES OF THE MENINGES

Spinal Puncture

This may be undertaken for diagnostic or therapeutic purposes or for inducing anæsthesia. Puncture is most often performed in the lumbar region, where the lumbar pond of fluid is tapped, and in the suboccipital region, where the cisterna magna (cerebello-medullaris) is entered. Lumbar puncture as we know it to-day dates from 1891, when it was first carried out by Heinrich Quincke of Kiel, while cisternal puncture was first performed in 1908 by Alexandru Obregia of Bucharest,‡ but was not adopted as a routine procedure until 1919, when Wegeforth, Ayer and Essick in the United States published details of their method of performing it.§

Indications.—Spinal punctures are made to obtain cerebro-spinal fluid for chemical, cytological and bacteriological examination; for the measurement of the fluid pressures; as a means of draining the subarachnoid spaces; for the introduction of therapeutic agents; for the introduction of air, either for the purpose of investigation or in order to break down arachnoidal adhesions and open up the fluid pathways; for the introduction of radio-opaque substances to ascertain the condition of the spinal subarachnoid space radiologically; and for the induction of spinal anæsthesia (*see* p. 448).

* *Brit. Journ. Surg.*, 1927-28, xv, 675; *Lancet*, 1935, i, 187

† *Rep. Ninth Congr. Soc. Internat. Chirurg.* Madrid, 1932, p 385

‡ "La Rachicentese sous-occipitale," *Comp. Rend Soc. Biol.*, 1908, lxv, 277.

§ *Amer. Journ. Med. Sci.*, 1919, clvii, 789.

Dangers and complications. *Damage to cord and infection.*—If incorrectly performed, the cord itself or the medulla at the cistern may be damaged, and hæmatomyelia and interference with conduction result; meningitis may occur if aseptic precautions are not fully observed, and it should be remembered that the cerebro-spinal fluid, unlike the blood, is devoid of antibodies.

Damage to intervertebral discs.—If the needle point traverses the dural tube and enters an intervertebral disc a fissure may be produced in the annulus through which nuclear material may subsequently herniate.* (*See* p. 464.)

Medullary compression.—In cases of internal hydrocephalus and raised intracranial pressure (e.g. such as may result from a tumour in the posterior fossa) in which there is herniation of the cerebellar tonsils

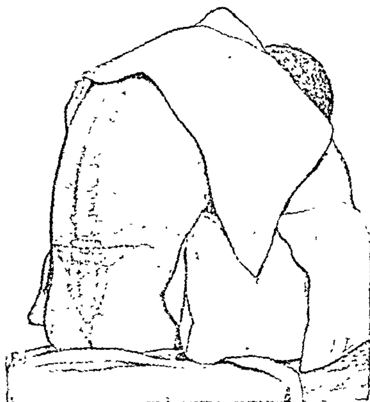


Fig. 163.—Sitting position for lumbar puncture

through the foramen magnum, the withdrawal of fluid by lumbar puncture may, by reducing the content of the water-cushion below the tonsils, permit further herniation, and a sudden fatality may take place from medullary compression. The danger of lumbar puncture in cases of high intracranial pressure (i.e. cases with highly choked optic discs) cannot be overstated. If at lumbar puncture the pressure is found to be unexpectedly high and it is necessary to remove a small amount of fluid for diagnostic purposes, a corresponding amount or slightly more than this of saline should be introduced into the lumbar pond to replace the fluid withdrawn.

* Pease, *Amer Journ Dis Child*, 1935, xlix, 849.

Headache.—Deviations from normal intracranial pressure, either in a positive or negative direction, may result in headache, and the lowering of pressure following spinal puncture may be followed by troublesome headache which persists for some time. This can often be relieved or avoided altogether by lowering the patient's head and giving a large quantity of water to drink. Acetylsalicylic acid is a useful analgesic.

Technique.—*Lumbar puncture* may be carried out either with the patient seated (Fig. 163) or lying on the side; the left lateral position is the one usually adopted (Fig. 164). The needles in use vary and may be of either the coarse or "gentil" type, or adapted to fit a manometer (Figs. 165, 166). The spine should be arched backwards so as to open out the interlaminar spaces; this is effected by flexing the patient's head and thighs as much as possible. It should be remembered that, provided the subarachnoid space is not obstructed,

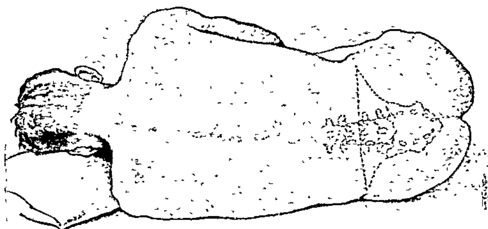


Fig. 164.—Left lateral position for lumbar puncture.

the pressure of the fluid in the lumbar pond will vary with the level of the patient's head in relation to that of the pond.

The skin of the lumbar region having been carefully sterilized, that point is noted at which a line connecting the highest parts of the iliac crests crosses the line of the vertebral spines. This point may conveniently be found by using the edge of a sterile towel stretched across the spine from the maximum point of convexity of each iliac crest. It lies either over the 4th lumbar spinous process or the interspace just above this process, i.e. between L.3 and L.4. This particular space may be selected or the one above, i.e. between L.2 and L.3, since in either case the needle will enter the lumbar pond below the conus medullaris. A wheal of local anæsthetic should first be made with a very fine and well-sharpened hypodermic needle. Through this wheal more anæsthetic is injected along what is to be the course of the spinal needle. The spinal needle should be entered directly in the

midline, midway between the spinous processes, and kept strictly in the sagittal plane, with its point directed slightly towards the head. If the point is felt to strike a lamina, its direction must be changed, still keeping the needle-shaft strictly in the sagittal plane, however, so that the point penetrates the ligamentum subflavum between the laminæ. At a depth of approximately 1 cm. beyond the ligament, the point of the needle is felt to be free and, on withdrawal of the stylet, *fluid escapes in drops.*

Lumbar puncture presents few difficulties, but in some cases there is a failure to withdraw the fluid. This generally means that the needle

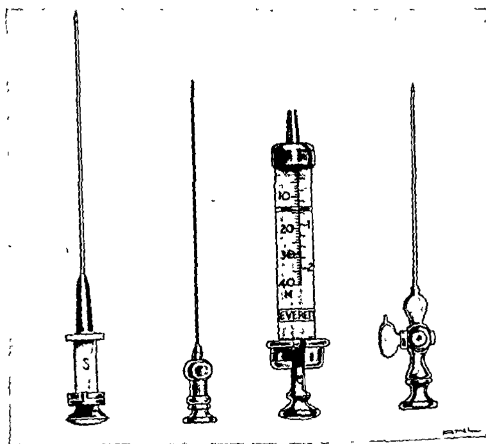


Fig. 165.—Syringe and needles used in spinal puncture.

has passed alongside and not penetrated the dura In these circumstances a few drops of blood may escape owing to injury to one of the veins If this occurs, it is preferable to withdraw the needle, wash it with sterile saline solution and re-insert it. If the needle strikes bone, and it is not possible to make it slide over its edge, it is also better to withdraw and re-insert it. With the spine horizontal, the head in the sagittal plane and the patient breathing quietly, *the normal pressure* of fluid in the lumbar pond is approximately 120 mm of water. Coughing, straining and pressure on the great veins at the root of the

neck normally cause rises in the pressure. Jugular compression normally produces a rapid rise to 300 mm. or more of water (Queckenstedt phenomenon).*

Cisternal Puncture

This may be carried out with the patient lying in the lateral position, but is most conveniently performed when he is seated with his head facing directly forwards, i.e. in the midline, but flexed so that the chin is on the chest, while an assistant stands in front and steadies the head in this position (Fig. 167). The hair has first been shaved off the back of the head, and the skin of this region and of the back of the neck has been sterilized An ordinary lumbar-puncture needle is used, and is passed so that the point enters in the middle line, midway between the posterior arch of the atlas and the under surface of the occipital bone. The needle point is directed upwards until it strikes the under surface of this bone and then, with the point against the bone and strictly in the middle line, it is slowly passed forwards until it is felt to penetrate the posterior occipito-atlantal ligament. (Fig. 168.) The stylet should be withdrawn, a small syringe attached to the needle, and the plunger of the syringe withdrawn, because the fluid in the cistern when the patient is in this position is at a pressure slightly below atmospheric and does not, therefore, always well out spontaneously when the cistern is entered. With the technique described the needle enters the cistern at its widest part immediately below the posterior margin of the foramen magnum. At this site the needle-point is usually separated from the medulla by a distance of about 2 cm.

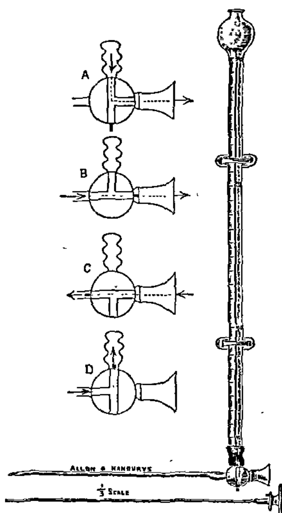


Fig. 166.—Greenfield's manometer for measuring the pressure of the cerebro-spinal fluid.

In cases of suspected spinal compression 1–2 c.c. of heavy lipiodol or "myodil" may be introduced through the needle into the cistern, and the patient subsequently X-rayed to ascertain whether the

* "Zur Diagnose der Rückenmarkskompression," *Dtsch Z. Nervenheilk*, 1916, lv, 325.

radio-opaque blob is arrested during its course through the subarachnoid space towards the lower limit of the meninges. (Plate II, facing p. 450.)

Alcohol Injections by Spinal Puncture for the Relief of Pain

In 1931 A. M. Dogliotti,* of Turin, suggested the use of intrathecal injections of absolute alcohol as a means of alleviating intractable pain. Such a simple procedure is of a comparatively minor character compared with chordotomy (p. 459), medullary tractotomy (Chap XXVI) or even rhizotomy (p. 458), and if safe and effective would

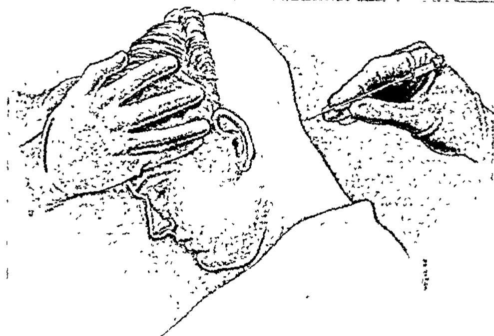


Fig. 167.—Cisternal puncture. In practice the face is shut off by a sterile towel.

have much to recommend it. Alcohol has a lower specific gravity than cerebro-spinal fluid, and by placing the subject in a position in which the posterior roots were uppermost, it was hoped that it would be possible to attack the posterior roots while leaving the anterior unaffected. Care being taken to avoid injury to the cord, a small lumbar-puncture needle is used to inject 0 2–1 c c. of absolute alcohol in the vicinity of the roots conveying the painful impulses, the patient lying prone and being kept in this position for at least ten minutes after the injection. In a few patients symptoms may be relieved almost at once, in others within a few hours, but paraplegia has followed in some cases and little or no relief of pain in others. Sphincter disturbances, manifested by retention or incontinence of urine or fæces, may also occur but have usually disappeared within a fortnight. The procedure must be described as uncertain in its results and

* *Pr. méd*, xxxix, 1249.

fraught with the possibility of unpleasant complications. Chordotomy is more certain in its results if the spinothalamic tract section is properly made.

Investigation of the Subarachnoid Space in Suspected Spinal Cord Compression

There are two methods of investigating the condition of this space: (1) by means of physical and chemical changes in the cerebro-spinal

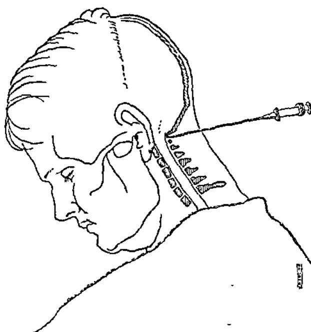


Fig. 168.—Cisternal puncture. Diagram showing the point at which the needle should penetrate the dura mater.

fluid; (2) by radiography after the introduction of suitable opaque substances. Chemical examination of the fluid obtained by lumbar puncture will show whether there is evidence of lumbar stagnation, the chief indication of which is increase in the protein-content without cellular proliferation, while the Queckenstedt phenomenon—the effect of jugular compression upon the pressure of the cerebro-spinal fluid in the lumbar pond—will enable inferences to be drawn as to the presence of complete or partial obstruction to the space (spinal block). (Fig. 169.)

The chief contrast media to be used in the spinal subarachnoid space have been air, iodine-containing oils of which the best known is "heavy lipiodol", a sterile poppy-seed oil containing 40 per cent. of iodine, first used in 1921 by Sicard and Forestier, of Paris,* and more recently preparations such as "pantopaque" and "myodil". Introduced into the cisterna magna by suboccipital puncture (p. 447), the blob of radio-opaque material, in falling through the subarachnoid

* *Rev. Neurol*, 1921, 28, vi, 1264.

space, is arrested at a site of obstruction. The appearance of the arrested blob may be due to the nature of the obstruction, so that from its shape it is sometimes possible to distinguish extra-medullary from intramedullary tumours or to recognize a condition such as meningitis circumscripta serosa. (Plate II.)

Myelography in suspect cases of spinal cord compression is both justifiable and desirable. It may be employed with advantage in the majority of cases of spinal tumour, even those in which the diagnosis is well-established and the level of the lesion definite, because the precise anatomical relationship between segments of the cord and the bodies and spines of the vertebræ is somewhat variable. Although clinical

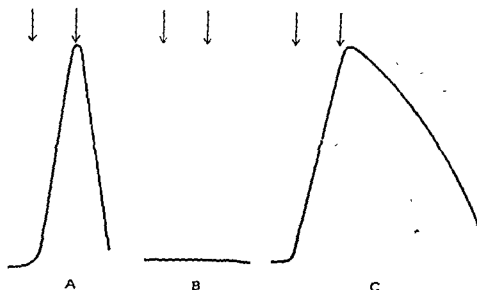


Fig. 169.—The Queckenstedt phenomenon. The arrows indicate the onset and release of jugular compression.

A, normal pressure wave Free circulation of cerebro-spinal fluid in the subarachnoid space, *B*, complete spinal block, *C*, *incomplete spinal block—a rapid rise has occurred but, because of partial obstruction*, the curve shows a flattening out and delayed fall In the case illustrated this was due to a small meningioma lying in front of the cord, which presumably acted like a "ball" valve.

examination may quite definitely indicate the site of the tumour at a particular segment, a myelogram so localizes this segment that its exposure may be made with the removal of a minimum number of *laminæ*.

Myelography of the lumbo-sacral region may be performed by introducing the opaque substance ("pantopaque," "myodil," etc.) into a lumbar pond of cerebro-spinal fluid through a lumbar puncture needle, and valuable information may thus be obtained in cases of lumbar disc lesion or cauda equina tumours.

LAMINECTOMY

Indications. - The operation may be indicated for (1) some cases of spinal injury, (2) certain inflammatory lesions; (3) tumours of the cord or its membranous or bony coverings; (4) spinal hydatid disease; (5) relief of pain by division of posterior nerve-roots or the sensory



(a)
Intrathecal extramedullary neurofibroma.



(b)
Intrathecal extramedullary meningioma.



(c)
Case of meningitis circumscripta serosa.

Note the helmet-shaped appearance of the blob in the tumour cases and its convex lower limit in the case of arachnoiditis.

PLATE II.—Myelography by the cisternal route.

tracts within the substance of the cord; (6) division of nerve-roots other than for pain, e.g., in conditions such as spasmodic torticollis and hyperpiesis; (7) section of extra-pyramidal tracts for such conditions as athetosis; (8) cases of herniation or prolapse of intervertebral discs; (9) certain cases of syringomyelia; and (10) certain other conditions such as compression paraplegia produced by Paget's disease (*see* p. 466) and rarely for epidural hæmorrhage.

1. Injuries.—Laminectomy is only rarely called for in cases of injury. From time to time surgeons have advocated immediate operation on all cases in which the condition of the patient permits, chiefly with the object of carrying out intra-pial decompression. Long ago A. R. Allen* showed experimentally that the symptoms produced by severe contusion of the cord may be relieved by incising the dorsal column at the level of the injury, thus allowing the swollen fibres to expand, and he concluded that it might be advisable "to perform laminectomy at the earliest possible moment and if the cord be not completely severed to make a median longitudinal incision through the area of impact by means of a fine caniculus knife in order to drain the injured tissue of the products of œdema and hæmorrhage". No series of successful cases so treated has, however, been reported and as an emergency operation in man, it must be remembered that the mortality is likely to be high and, except in expert hands, further damage to the cord may be produced beyond that of the original contusion In the majority of cases of fracture-dislocation, any damage to the cord is done by a sudden nipping at the time of the accident. The cord may be contused or lacerated and a hæmatomyelia may arise at the site of the damage, but these are not lesions for which surgery is indicated. Extra-medullary hæmorrhage of sufficient degree to cause compression of the cord is very rare, and provided early and complete reduction of a fracture-dislocation is effected, and maintained by a plaster of Paris jacket, the cord is unlikely to be compressed subsequently. If there be any doubt as to whether there is cord compression, the state of the subarachnoid space should be investigated (*see* p 449).

Injuries of the cord in civil life are nearly always associated with fracture-dislocations of the vertebræ. The great majority of these lesions are produced by hyperflexion, and commonly occur in the lower cervical (e.g , diving into shallow water) and lower thoracic and upper lumbar regions (e.g , falls of mine-roof, cargo, etc., on the bent shoulders). From the very first moment, the patient must be guarded against further flexion of the spine which may convert an incomplete into a complete lesion, e.g , in the case of the more common thoraco-lumbar lesion he should be carried from the site of the accident fully prone so that the body weight keeps the spine extended. The spinal column must then be immobilized in a position of hyperextension by means of a plaster jacket.

* *Journ Amer Med Assoc*, 1911, lvii, 878

The question of laminectomy in spinal injuries is a difficult one, and any decision regarding operation must depend upon a conception of what surgical intervention might be expected to accomplish. Pressure on the cord may be exerted by a missile or in-driven fragment of bone and, while the resulting compression is not progressive and therefore does not demand immediate relief, recovery of a contused cord may be delayed by the presence of the foreign body. Laminectomy in such cases may, furthermore, prevent late complications such as cicatricial contraction and interference with the cerebro-spinal fluid circulation.

Gunshot injuries.—If seen early, e.g., within eight hours, and if the patient's condition permits, excision of the wound should be carried out at once and the spine immobilized in plaster. If, as sometimes happens, there has been a good deal of loss of substance so that after excision it is not possible to approximate the wound edges, a vaselined gauze pack should be introduced into the excised wound and the spinal column immobilized in a plaster jacket. Chemotherapy is indicated and penicillin should be used locally as well as systemically. The case may not, however, be seen until some time has elapsed, and the problem of operation is then complicated by the almost inevitable infection of the tissues. No operation which entails opening the theca is permissible in the presence of a septic wound, on account of the danger of causing septic meningitis.

Except in the early case of compound injury when the operation is performed with the object of protecting the patient from infection, laminectomy is better avoided during the period of spinal shock (*see* p. 441), when the functional depression may be sufficient to turn the scale against recovery from what is a severe operation. Furthermore, during the phase of spinal shock it is not possible to estimate the degree of damage to the cord nor to recognize whether the lesion is complete or not, and operations for complete transverse lesions of the cord are futile. Once the cord has been completely divided, recovery of its distal part does not take place. This does not apply to the elements of the cauda equina which, like medullated nerves, should be sutured when divided. Successful suture of the cauda equina must, however, be exceedingly rare. The Official History of the 1914–18 War states, "It is a little remarkable that not a single example has been met with in which the cauda equina has been sutured." The position has not been altered to any great extent by the recent war, odd cases in which attempts at suture have been made are known, but it is only exceedingly rarely that suitable conditions for suture present themselves

Once spinal shock has passed off it becomes important to know whether the cord lesion is complete or not. This may be apparent from the nature of the injury, which may be such that it is certain the cord has been divided, e g., gross displacement of vertebræ upon one another, together with complete absence of any evidence of conduction , but in most cases a decision has to be made from neurological

examination alone. It should be remembered that a mass-flexion reflex with a return of knee-jerk and ankle-jerk may sometimes be present with a complete transverse lesion of the cord, and hence is of no decisive value. Spastic paraplegia in extension, however, means that the spinal reflex arcs are in communication with intracranial centres by means of the extrapyramidal tracts, and therefore that the cord lesion is incomplete; similarly, if there is any sensation of light touch over the skin of the limbs distal to the site of injury of the cord, the spino-thalamic tracts are capable of some conduction and the cord lesion is incomplete.

If, when the period of spinal shock has terminated, there is evidence that the cord lesion is not complete, laminectomy is indicated if (*a*) gross bony deformity is present, or a missile is demonstrated radiologically in close proximity to the cord. Operation, by removing the source of a local reaction, will now assist the restoration of conduction and guard the patient from complications in the form of scar tissue and adhesions*; (*b*) an arrest takes place in the recovery of conduction through the damaged cord, i.e., the patient's progress ceases to be maintained; or (*c*) there is persistent and severe root-pain.

In later cases the problem is simpler. The onset of any symptoms pointing to late local reaction, e g., root-pain or meningitis circumscripta serosa, calls for laminectomy.

The **indications for operation** in cases of spinal cord injury may be summarized as follows:—

1. Early cases of compound fracture when the patient's condition permits, immediate excision of the wound with the object of guarding him from subsequent infection.
2. Cases clinically incomplete from the beginning in which progress becomes retarded or arrested.
3. Cases which, when spinal shock has passed off, prove to be incomplete lesions.
    (*a*) If the progress is not maintained.
    (*b*) If a foreign body or piece of bone is lying in close proximity to the cord.
    (*c*) If there is continued sepsis
4. Cases showing the onset of symptoms at a late period.

2. **Inflammatory lesions.**—Intramedullary inflammatory lesions are not usually amenable to surgical treatment but a few rare cases of abscess in the substance of the cord with recovery of function following laminectomy and evacuation have been reported.†

Inflammatory lesions of the meninges are either acute and diffuse, or localized and chronic. In the former no improvement can, as a rule, be obtained from operative means other than by repeated drainage

* Posterior roots damaged at the side of the cord lesion should be divided to protect the patient from root pains which may otherwise be troublesome

† A J. Walton, *Lancet*, 1919, i, 243. H. W Woltman and A. W. Adson, *Brain*, 1926, xlix, 191.

by spinal punctures followed by the intrathecal injection of appropriate antibiotics. The more chronic forms are either due to syphilis, when the Wassermann and Kahn reactions will be helpful and a course of anti-luetic treatment given a trial before operation is undertaken; or else constitute meningitis circumscripta serosa (chronic spinal meningitis of Horsley). The latter condition may clinically simulate spinal tumour but, generally speaking, because of its rather diffuse character, is more difficult to localize to a particular segment or segments. The appearance of the myelogram is characteristic and serves to differentiate the condition, when occurring in a localized form, from spinal tumour (Plate II, facing p. 450). The findings at operation are characteristic; the arachnoid is matted into strands which have an opaque, rope-like, whitish appearance suggestive of previous inflammation. As a rule some improvement follows the freeing of the cord from these strands but relapses are common.

Inflammatory changes in the substance of the bone may be due either to osteomyelitis or to tuberculosis, in which case radiology may be helpful in establishing the diagnosis. If osteomyelitis is recognized, it should be treated before there is evidence of cord compression. In the acute pyogenic variety there is pain in the back, pyrexia and leucocytosis, the onset is usually sudden and there may be rigors Treatment is by prolonged recumbency, chemotherapy and plaster jackets. New bone function is characteristic of the later X-ray appearances in well established cases * In tuberculous osteomyelitis recovery nearly always follows the application of adequate immobilization and general treatment, and such measures therefore should always receive a trial before operation is considered. Operation, however, may be required. (1) if there is a progressive increase of symptoms in spite of orthopædic treatment; (2) if there are distressing complications such as severe root-pains; or (3) if symptoms appear late and are due to scar tissue.

Intraspinal abscesses have occasionally been met with, the origin of which is obscure.

3. **Spinal tumours.**†—Tumours may arise from the vertebræ; the meninges, the cord itself, its nerve-roots or its blood vessels Anatomically they may be classified as extra- or intra-thecal and as extra- or intra-medullary, pathologically as either benign or malignant, primary or secondary, while histologically the varieties are many. A review of a large series of cases shows that more than three-fourths of all spinal tumours occur outside the spinal cord, and that these extramedullary tumours are three times more often met with inside than outside the theca Of intrathecal tumours more than two-thirds occupy a dorsal or dorso-lateral position in relation to the cord. Tumours of the cord and meninges occur most frequently in the

* Peter Martin, *Brit med Journ*, 1946, ii, 688

† Victor Horsley in 1887 was the first to remove a spinal tumour successfully. It was intrathecal and extramedullary, and produced paraplegia from which the patient, an army officer aged 42 made a complete recovery The tumour was almost certainly a neurinoma

thoracic region. Intrathecal, extramedullary tumours are usually either meningiomas arising in the arachnoid, or neurinomas arising from nerve-roots.* (Figs. 196a, b, p 478.)

It is important to diagnose, localize and operate on cases of spinal tumour as early as possible. In a few cases this may be done before

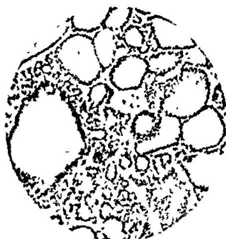
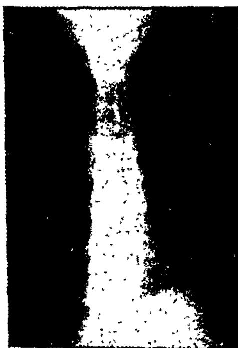


Fig. 170.—Myelograms and microscopical appearance ($\times 100$) of metastatic *thyroid tumour causing cord compression* and paraplegia, removed from the lamina of D.9 of a man aged 44.





compression has produced paraplegia, but the majority do not present themselves until some degree of paraplegia is established. Obscure cases of spastic paraplegia should always be regarded as suspect cases of spinal tumour and the condition of the subarachnoid space investigated for evidence of encroachment upon it (spinal block). (*See*

* Lambert Rogers "The Surgery of Spinal Tumours," Hunterian Lecture, R C.S., *Lancet*, 1935, i, 187, also "Tumours Involving the Spinal Cord and its Nerve Roots," Bradshaw Lecture, R C S, 1955, *Ann of R C.S*, xvi, 1

p. 449.) In the past I have removed tumours from several patients who had been regarded as suffering from disseminated sclerosis. Such a mistake in diagnosis is not likely to arise to-day.

Spinal tumours exerting pressure on the cord must be differentiated from other causes of cord compression and from degenerative lesions within its substance, because in each case a clinical picture of paraplegia or tetraplegia is produced by interruption of conduction. The condition of the subarachnoid space (p. 449) is all important in differentiating compression from degenerative lesions within the substance of the cord.

Compression paraplegia of rather abrupt onset is frequently due to a metastasis in the spine and careful examination should be made to find the primary tumour. I have met paraplegias of this type in which the primary tumour was in the thyroid, kidney, breast, prostate, bronchus and the testis respectively. (Fig. 170.)

The clinical course of the great majority of spinal tumours is comparatively slow but steadily progressive without remission ("slow but remorseless," Percy Sargent). By contrast, in acute inflammatory conditions such as extradural abscesses, the course is relatively short and associated with pyrexia, while in chronic inflammatory lesions, such as meningitis circumscripta serosa, it tends to be a variable one with remissions, and the segmental level indicating the site of compression is indefinite and variable. In Pott's disease there may be characteristic X-ray appearances and in hydatid disease the blood picture and the cutaneous and serum reactions may establish the diagnosis. In a series of spinal-tumour cases it was found that a feeling of coldness or numbness, especially in one foot, was frequently the initial symptom; in others some form of girdle pain occurred at the onset; while in still others weakness (e.g., of the arm or dragging of a leg) was the initial symptom.* The Brown-Séquard type of paralysis which is consequent upon a unilateral cord lesion (i.e., motor paralysis on the side of the lesion and loss of pain, temperature and tactile sensation below the lesion on the opposite side) is only rarely seen and then usually in association with tumours in the cervical region. A partial picture was produced in one of my patients, a man aged 23, who had a large tumour compressing antero-laterally the 1st and 2nd cervical segments on the right side.† The rarity of the Brown-Séquard phenomenon probably depends upon the fact that even small lateral displacements of the cord by tumour result in compression not only on the side of the tumour, but also at the diametrically opposite point in the spinal canal, at which the cord is displaced against the bone. By the time the majority of laterally-placed tumours manifest their presence, hemi-compression has become bilateral compression. The greater transverse diameter of the cervical part of the vertebral canal probably accounts for the occasional presence of the syndrome in association with spinal tumours occurring

* A. M. Kennedy and Lambert Rogers, *Lancet*, 1928, i, 225; 1930, i, 854

† The tumour was a neurinoma. The patient is alive and well 25 years after his operation and is working as an engineer.

in this region. The common intrathecal tumours are neurinomas arising in connection with the nerve-roots or meningiomas in relation to the membranes.

In common with Schultze, of Berlin,* Geoffrey Jefferson† and others, I have noted the comparative painlessness of certain spinal tumours. Some form of girdle pain, however, is often prominent, and this root-pain has sometimes led to mistakes in diagnosis. A patient with a spinal tumour which I removed had previously had appendicectomy performed and an exploration of kidney advised for root-pain, the nature of which had not been recognized. The possibility of root irritation as a cause of pain should always be kept in mind.

An even commoner mistake than failure to recognize root-pain, however, is failure to differentiate between spinal tumours and degenerative lesions in the substance of the cord, of which the commonest is disseminated sclerosis. In five of my series of tumour cases, a diagnosis had at one time been made of disseminated sclerosis, in two of them by two different consultants.‡ In miners, many of whom have nystagmus, there is perhaps an even greater tendency to diagnose disseminated sclerosis. We should, therefore, be suspicious of a diagnosis of disseminated sclerosis, especially if the clinical course is a steadily progressive one. If there is the least doubt, it is better to regard the case as a spinal-tumour suspect, and to investigate the condition of the subarachnoid space for the presence of obstruction. If obstruction exists, then the case becomes more than suspect and exploration is called for.§

Cord compression may be due to plasmocytoma or lymphadenoma, either solitary tumours or as part of one generalized disease.‖

4. **Hydatids.**—In 1897 Sir Victor Horsley reported¶ the case of " a man with symptoms of compression at the level of the region of the 3rd lumbar nerve ; on opening the spine at the 12th dorsal vertebra we found it was due not to a new growth, but to a multiple hydatid cyst of the vertebral column." Many cases have been reported since, and in areas where hydatids are found such a cause of compression has to be remembered The Casoni reaction may be positive and the blood picture often shows an eosinophilia. The cysts are nearly always extradural and usually multiple (Fig. 171) and may deeply invade the body of one or more vertebræ.

5. **For the relief of pain by division of posterior nerve-roots or the sensory tracts within the substance of the cord.**—The demoralizing effect of the continued exhibition of analgesic drugs such as morphia has called forth efforts to relieve intractable pain by surgical means. At the level of the spinal cord there are two methods available : (i) division of the posterior spinal roots conveying pain impulses into the cord

* *Dtsch med. Woch*, 1912, xxxviii, 1676.
† *Brit Med. Journ*, 1928, ii, 200
‡ *Lancet*, 1935, i, 187.
§ Lambert Rogers, " Laminectomy for Spinal Tumours," *Journ. Coll Surg.*, Australasia, March, 1931, iii, 3, 311.
‖ Lambert Rogers, *Brit J. Surg*, 1953, xli, 54
¶ *Clin. Journ*, Jan. 13, 1897, p. 182.

(posterior rhizotomy), and (ii) section in the cord itself of the tracts conducting painful sensory impulses to the brain.

(i) *Posterior rhizotomy.*—Since it was first suggested in 1888 by Charles Dana as a means of relieving pain, the operation has also been performed with the object of abolishing or diminishing spasticity. It is frequently known as Foerster's operation, after Otfried Foerster, of Breslau, who developed the technique and brought the operation to the notice of the profession. Foerster performed posterior rhizotomy for gastric crisis in the belief that the pain was due to the exalted activity of the reflex arc,* and for spasticity resulting from cerebral



Fig. 171.—Hydatid cysts may cause cord compression necessitating laminectomy. Those shown were a cause of extradural compression paraplegia (4,D) in a man aged 20 and were removed by laminectomy. (*Author's case*)

diplegia (Little's disease), since it had been observed that if a patient with disseminated sclerosis developed a posterior column and root lesion, e.g., tabes, the spasticity due to the sclerosis tended to decrease as the posterior-column disease progressed.

For trigeminal neuralgia, posterior-root section is eminently successful, and has the great advantage that since the section is made central to the Gasserian (posterior-root) ganglion, regeneration does not take place and the relief of pain is, therefore, permanent. Similar relief follows in cases in which pain arises from isolated spinal nerves, as in persistent intercostal neuralgia. Except for such cases, however, and cases of pain due to the posterior roots themselves being involved in some disease process, e.g., strangled by arachnoiditis, or damaged by injury, the results of posterior rhizotomy as an analgesic measure are unsatisfactory. This is chiefly owing to the wide sensory overlap which necessitates the division of a large series of roots, and to the fact that, owing to interference with reflex activity, such extensive division cannot be carried out without causing ataxia. If the whole of the

* *Surg. Gyn. Obstet.*, 1913, xvi, 463.

posterior roots of a limb plexus are severed, the limb becomes practically useless. Posterior rhizotomy of one or two roots may be of value in recurrent arachnoiditis following the removal of a tumour. A patient of mine, a spinster aged 56, recovered from paraplegia following removal of a meningioma compressing the thoracic cord. Two years later, however, she developed intense root pain along the course of the 9th and 10th intercostal nerves. At a further operation performed some 10 years ago I found the roots of these nerves to be invested by adhesive arachnoiditis; her pain was immediately relieved by their division and she has remained well since and free from any

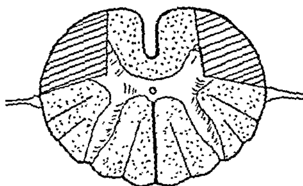


Fig. 172.—Diagram showing extent of section made in chordotomy for the relief of pain.

recurrence of her pain. The results of posterior root section performed for spasticity have not as a rule been encouraging, but recently Falconer and others have reported favourable results in cases of partial section of several roots. Some relief from the distressing spasms to which patients with complete cord lesions are subject has been given by anterior rhizotomy performed over a number of segments according to the level of the lesion. Bilateral obturator neurotomy and various tenotomies may also be helpful in these cases.

(ii) *Chordotomy.* (A) *Antero-lateral tract section.*—In 1910, A. Schüller, of Vienna,* suggested division of the antero-lateral tracts for the gastric crises of tabes, and introduced the term chordotomy for the suggested operation. The following year W. G. Spiller, of Philadelphia, carefully observed a patient who had completely lost pain and temperature sensations in the lower limbs and at autopsy was found to have had each Gower's (antero-lateral) tract destroyed by a solitary tubercle; Spiller suggested that this tract might be divided for the relief of pain in a case of malignant growth in the cord. The operation was first performed on January 19, 1911, by Edward Martin, who divided both antero-lateral tracts to a depth of 2 mm. at the level of the 7th thoracic vertebra. Pain was alleviated, and a year later Spiller regarded the result as successful.†

The antero-lateral section of the cord should include a small portion

* *Wien med Woch*, 1910, lx, 2292.
† *Journ Amer. Med. Assoc*, 1912, lviii, 1489

of the anterior column of grey matter, since it is held by some that visceral sensations are carried therein by short chain pathways (Fig. 172.) The pain-fibres cross obliquely in the cord and in order, therefore, to ensure their complete division, the level of the section should be at least four segments above that of the lesion. The division is usually carried out at the 4th, 5th or 6th thoracic segment, two or three laminæ being removed for the purpose, but high cervical operations have also been performed with success, particularly in cases of causalgia and phantom limb.* While unilateral chordotomy in the middle or upper cervical region is safe, a bilateral operation at this level, particularly when carried out as a one-stage procedure, is fraught with the danger of respiratory paralysis.

(B) *Posterior longitudinal section.*—In 1926, Donald Armour,† acting on the suggestion of Dr. G. Greenfield, performed a posterior median section of the cord for a patient suffering from severe gastric crisis. In this operation advantage is taken of the fact that the pain-fibres cross obliquely over the course of several segments; it is the decussation which is divided, and the direction of the section is such that no injury to the pyramidal tracts can occur. The procedure has been likened to the production of an artificial syringo-myelia by division of the median commissure which is destroyed in that disease. The section must obviously be carried out just above the level of the lesion. A median longitudinal incision about 1 in. in length, at the level of the 11th and 12th dorsal and 1st lumbar segments, destroys all pain fibres from the lower limbs and pelvis. This operation may be performed on the cervical cord for intractable pain in the arms; e.g., in a case of intense pain in the arm, due to carcinomatous deposits in the axillæ, relief followed it.‡

Opinions vary as to the exact position of the spinothalmic tract in the cord. O. R. Hyndman and C. Van Epps§ have compared the position of the tract as defined in various textbooks with their own findings. (Fig. 173.) The spinothalmic fibres from the higher segments are placed anterior to those from more caudal ones. By dividing only the anterior portion of the tract, therefore, it is possible to abolish pain in the upper part of the trunk without interfering with this sensation in the lower limbs. The dentate ligament is attached somewhat posterior to, and not, as usually believed, at the coronal axis of the cord. As low as the fifth thoracic segment the anterior limit of the tract extends in front of the line of attachment of the anterior nerve roots. Hyndman and Epps' findings are the result of their experience of 41 chordotomies, 6 of which were performed under local analgesia.

Results of chordotomy.—Chordotomy may be followed by weakness in the legs, bladder and rectal sphincters, and severe muscle spasm

* Lancelot Bromley, Guy's Hosp Reports, April, 1930, Murray Falconer and F. G. B Lindsay, *Brit J Surg*, 1946, xxxiii, 301.

† *Lancet*, 1927, i, 691

‡ T J. Putnam, *Arch Neurol Psych*, 1934, xxxii, 1193

§ *Arch Surg*, 1939, xxxviii, 1036.

in the legs and back,* and intense girdle pains have also been noted. Such untoward symptoms are usually temporary and clear up within the course of a few days or weeks, if the section has been properly performed. These transient pyramidal effects are probably due to œdema, hæmorrhage or traumatic myelitis. The intense girdle pain at the level of the cord section may be avoided by dividing two or three posterior roots at this site. G. F. Stebbing† recorded a series of 17 cases on whom he had performed section of the antero-lateral

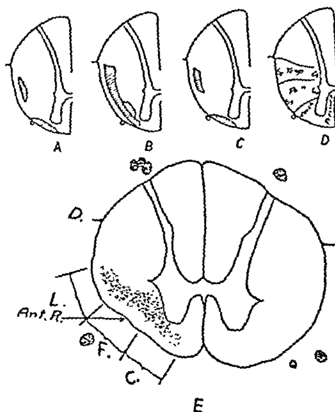


Fig. 173.—Diagrammatic representations of the spinothalamic tracts as given by several authors.

tracts; 11 operations were for inoperable cancer and 5 for tabes. There were 2 deaths; in the remaining 15 cases the measure of relief appeared to justify the operation, and in none was there any permanent ill-effect. In the tabetic cases, however, the pain tended to return a year or more after the operation. H. Schloebmann‡ has recorded his experience of 24 cases of chordotomy. The patients were observed for more than one year, most for over three years after

* P. G. Flothow, *Surg. Clin. N. Amer.*, 1933, xiii, 1345
† *Lancet*, 1929, i, 654.
‡ *Arch. klin. Chir.*, 1933, clxxvii, 565.

operation ; 3 were completely relieved, 6 were improved, their pain being much diminished, while 1 case of herpes zoster failed to respond.** When relapses occur after chordotomy it has been suggested that they may be due to the opening up of auxiliary conducting pathways (Foerster), but they may also be due to incomplete section of the tract, and Peake and Kahn* have recently emphasized the necessity of extending the incision well forwards, care being taken not to damage the anterior spinal artery. If a bilateral operation is performed the two incisions in the cord should not be placed immediately opposite each other otherwise the blood supply to the cord may be jeopardized. I have found chordotomy of distinct value in a few cases of intense pain due to malignant disease.

6. **Rhizotomy other than for the relief of pain.**—(i) *Spasmodic torticollis* has been treated by high cervical laminectomy with division of both the anterior and posterior roots of the first three cervical nerves combined with extra-cranial section of the spinal accessory nerve;† while some satisfactory results have been reported, others have been disappointing.

(ii) *Hyperpiesis.*—Section of the 6th thoracic to the 2nd lumbar anterior nerve-roots has been performed in an attempt to lower blood-pressure and relieve symptoms in malignant hypertension.‡ This operation has, however, been replaced by sphlanchnic and sympathetic nerve resections (*see* p. 503).

(iii) *Spasticity.*—Partial section of a number of posterior roots has proved helpful in some cases of spasticity following cord injury.

7. **Tract sections performed other than for the relief of pain.**—In 1924 Spiegel§ suggested dividing the extrapyramidal tracts (Fig. 174) for the relief of spasticity, and attempts have also been made to treat paralysis agitans by a similar section. By severing the non-pyramidal motor pathways such as the vestibulo-spinal, reticulo-spinal and tecto-spinal tracts, which lie in the anterior part of the cord, it was hoped to mitigate symptoms on the same side below the level of the section, but results have not been particularly encouraging. In 1931 Tracy Putnam‖ performed extrapyramidal tract section for athetosis, and in March, 1940,¶ reported 50 operations performed for this condition on 38 patients with 4 post-operative deaths. (Fig. 175.) Most of the patients were pleased with the result of the operation even if it only enabled them to lie quietly in bed or sit up in a chair when this had previously not been possible, but no patient had been completely relieved and the operation appears to have been abandoned; with the exception of division of the spinothalamic tract for the relief of pain, section of the other conducting tracts in the cord is rarely practised to-day.

** J. C. White, W. H. Sweet, R. Hawkins and R. G. Nilges (1950, *Brain*, lxxiii, 346) found that of 210 patients operated upon between 1936 and 1948 there was a mortality of 4 per cent. Fifteen per cent. were unrelieved. Retention of urine was more likely to follow a bilateral one stage operation but when it occurred was usually recovered from in 1 or 2 weeks' time.

* *Journ. Neurosurg.*, 1948, v, 276.
† Dandy, *Arch. Surg.*, 1930, xx, 1021.
‡ Adson, *Proc. Staff Meeting, Mayo Clinic*, 1933, viii, 739.
§ *Jahrb. f. Psychiat. u. Neurol.*, 1924, xliii, 165.
‖ *Arch. Neurol. and Psych.*, 1933, xxix, 504.
¶ *New Eng. Surg. Journ.*, 1940, ccii, 473.

Dorsal chordotomy.—Division of the dorsal columns (of Goll and Burdach*) has been performed for cases of persistent and painful phantom limb, the discomfort of which would appear to be due to a cortical misinterpretation of an uncomfortable position of the phantom part, e.g. a cramped, squeezed or twisted position of absent fingers. For the upper limb the inner two-thirds of the dorsal column on the side concerned is divided at the level of the second cervical segment; for the lower limb the whole column is sectioned in the mid-thoracic region. Results in the few cases in which this operation has so far been performed have been encouraging.

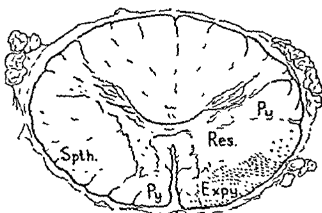


Fig. 174.—Diagram of the principal pathways in the cervical cord showing the position of the extra-pyramidal tracts (*Expy*) relative to the pyramidal (*Py*) and spino-thalamic (*Spth*) tracts.

(After Tracy Putnam, *Journ Bone & Joint Surg*, 1939, xxi, 952)

8 **Herniation or prolapse of intervertebral discs.**—In 1858 Hubert Luschka† noted posterior nodal protrusions of intervertebral discs and correctly interpreted these as chordal remnants In 1896 Theodor Kocher‡ reported a case of rupture of the intervertebral disc between the 1st and 2nd lumbar vertebræ in a young man who had succumbed to multiple injuries after falling from a height of 100ft. and landing in a standing position. There was no fracture of the spine. In 1911 Middleton and Teacher of Glasgow reported a case of fatal paraplegia in a man aged 38 in whom, when lifting a heavy weight, rupture of the disc between the 12th thoracic and 1st lumbar vertebræ occurred and compressed the conus.§ Nodules projecting backwards into the neural canal from the region of the discs have long been recognized, and have been variously regarded as myxo-chondromas, fibromas, loose cartilages or fibro-chondromas. These are now recognized as extrusions of the nucleus pulposus of the intervertebral disc through an annulus

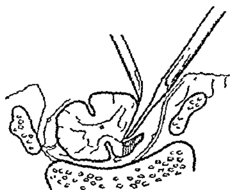


Fig. 175.—Diagram of the operation of extrapyramidal tract section. The cord has been rotated and an incision made at the level of the anterior root attachments.

(After Tracy Putnam, *Arch Neurol & Psychiat*, Chicago, 1938, xxxix, 263.)

* Jefferson Browder and John P Gallagher, *Ann Surg*, 1948, cxxviii, 456.
† Die Halbgelenke des menschlichen Korpers, Berlin, 1858.
‡ *Mitt Grenz geb Med Chir*, 1896, i, 415
§ For an account of this and other cases which have led to our knowledge of disc lesions, see "The Intervertebral Discs and Sciatica," Lambert Rogers, *Journ. R N med Service*, 1950, xxxvi, 125

weakened or ruptured by injury or some form of degeneration. (Fig. 176.) Injury by a lumbar puncture needle has been regarded as an infrequent cause of fissuring. As a result of vascularization subsequently, the herniated nuclear material may undergo calcification or ossification. It may be responsible for compression of the cord or the cauda equina or of one or more nerve roots, and such compression radiculitis is a frequent cause of sciatica and pain in the lumbar region. Certain cases of obscure back pain are probably due to these herniations stretching the posterior common ligament.* In cases of disc protrusion, the cerebro-spinal fluid may contain an increased amount of protein. If this is considerably raised (e.g., above 100 mgms.), either a massive disc protrusion or a cauda equina tumour

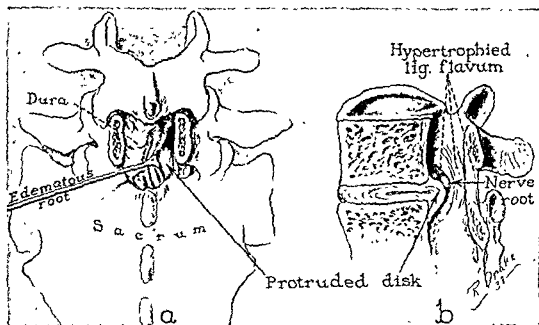


Fig. 176.—Protruded intervertebral disc.

In (a) a swollen nerve root is shown retracted away from the herniated disc. In (b) the protrusion is seen in sagittal section (Reproduced by permission of the Hon. Editors, from J. Grafton Love, Proc. Roy. Soc. Med., 1939, xxxii, 1708.)

should be suspected. There is a good deal of difference of opinion on the frequency with which discs herniate and cause symptoms. Dislocations are occasionally found at autopsy and yet have been symptomless during life. As a cause of "sciatica" disc lesions probably account for most cases. There is evidence that these lesions develop in discs which are already the subject of some degenerative change.†

"The disc protrusions which cause sciatica occur in the lower lumbar region and are relatively common, but similar disc lesions may occur in the cervical or dorsal regions where they may cause cord compression and paraplegia and thus in their clinical manifestations simulate tumours of the cord. If the herniation is more lateral, root pain may be the outstanding feature and a lesion of the disc between C.5

* Mixter and Barr, *New Eng. Journ. Med.*, 1934, ccxi, 210. † O. R. Hyndman, *Arch. Surg.*, 1946, lii, 247

and C.6 or C.6 and C.7 is sometimes a cause of brachial radiculitis.* The disc lesions which most commonly cause sciatic radiculitis are those of L.5–S.1 or L.4–L.5. The lumbo-sacral disc is the one most often at fault. Pain is sciatic in distribution, tending to radiate towards the outer side of the foot if the lumbo-sacral disc is involved, towards the inner side if the lesion is in the disc between L.4 and L.5. The pain is usually intermittent, increased by coughing, sneezing or straining and relieved by rest. Leg raising is limited (*Lésegue's sign*) and the ankle jerk may be lost or diminished. There may be some wasting of the thigh and leg muscles and an associated scoliosis of the lumbar part of the spine. In persistent cases of sciatica, lumbar puncture should be performed and if the protein content of the fluid is much increased, a gross protrusion of disc contents or a tumour of the cauda equina should be suspected. I have removed a tumour from a woman aged 39 who had had sciatica for 13 years and was regarded as hysterical. The protein content of the fluid was 290 mgms There were no sphincter disturbances and her only complaint was sciatica which was completely relieved after removal of the tumour, a meningioma." (L.C.R.)

Results of operation on lumbar discs.—R. Glen Spurling and E. G. Grantham† reviewed 378 cases operated upon between 1939 and 1947 for sciatica refractory to conservative measures. One patient died on the tenth day after operation from broncho-pneumonia. The patients were aged from 16 to 74; 257 were men, 121 women. In 30 cases exploration was negative, in 5, ruptures of 2 discs were found. Forty per cent. of the 327 cases traced were regarded as cured; 85 per cent. could do the same work as before operation; 13 of the 30 cases of negative exploration were regarded as cured.

Fewer operations for intervertebral disc lesions causing sciatica or back pain are being performed to-day than was the case a few years ago. Many of these patients recover with conservative treatment and rest in bed or orthopædic rest, e.g., plaster of Paris. In some manipulation is effective.

9. Syringo-myelia.—Operation for this condition was apparently first carried out by Sir Victor Horsley, who, however, never published the case Dr Anthony Feiling has related how Horsley incised the cord and the cerebro-spinal fluid spurted out. In 1916 Elsberg opened into a syringo-myelic cavity when exploring the cord for an intramedullary tumour and there was subsequently some amelioration of the patient's condition Following a report by Puusepp‡ of striking improvement in a patient upon whom he had operated in 1926, Jirasek,§ Kelly,‖ C H. Frazier and S. N. Rowe¶ and others have given

* A good deal of attention has recently been paid to osseous changes in the cervical spine in association with degenerative changes in the intervertebral discs (cervical spondylosis) as a cause of cord symptoms or root pain Osteo arthritis of the neuro-central joints of Luschka may be present and the intervertebral foramina may be narrowed in such cases. (Russell Brain, 1954, *Lancet*, i, 687, and C Pallis, A. M. Jones and J D Spillane, 1954, *Brain*, lxxvii 274.)

† *J Neurosurg*, 1949, vi, 57.

‡ *Presse Méd*, 1932, xl, 103

§ Report of 25 cases to Moynihan Chirurgical Club, 1933

‖ Report of 10 cases, *Trans. Med Soc*, 1935, lviii, 141.

¶ *Ann Surg*, 1936, ciii, 481.

their experiences of operations for syringo-myelia. The object is to drain the cavities in the cord in the hope of thereby relieving tension and reducing œdema but, although there has been some slight improvement in a few patients, the results for the most part have been disappointing. Operative treatment is unlikely to retard the progress of the disease or improve cord conduction unless tension and compression are factors. Unless, therefore, there is encroachment upon the spinal subarachnoid space, as shown by appropriate tests (*see* p. 449), surgery has not much to offer in cases of syringomyelia. If operation is undertaken, a posterior vertical myelotomy in the midline, or a few millimetres lateral to it on the side of the greater

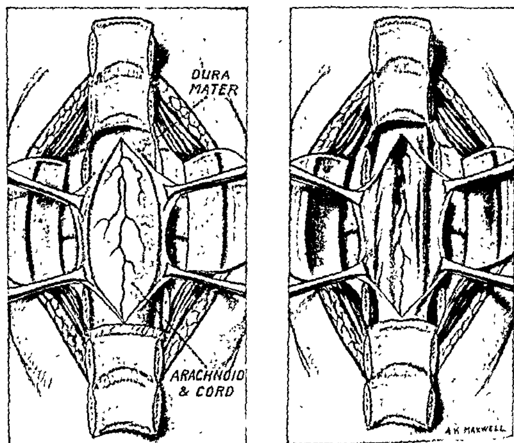


Fig. 177.—Laminectomy and incision of cord for syringo-myelia.
(Reproduced by permission from Worster Drought, Wakeley and Shafar, *Brit Journ Surgery*, 1941, xxix, 70)

cord damage, is the procedure of choice. (Fig. 177.) Wound healing in this disease may be retarded and troublesome.

Jefferson* finds that the operation has no permanent effect on symptoms and no curative effect on the process itself

10. **Certain other conditions such as paraplegia produced by Paget's disease.**—J. W. Aldren Turner has analysed 18 cases of spinal compression due to this disease.† Numbness and weakness of the leg advancing to spastic paraplegia accompany the typical bony changes

* *Lancet*, 1941 ii, 714. † *Brain*, 1940, lxiii, 321

seen in radiography. Pain may be troublesome. Decompressive laminectomy is of value: the bone is soft and bleeds considerably. I have operated on one case, a man aged 61 who made a gratifying recovery from his paraplegia, and for some years was able to continue his work as a supervising engineer.

11. Extradural hæmorrhage is very rarely a cause of cord compression and an indication for laminectomy. Only rarely is injury a cause, though some form of strain has occurred in most cases and in some recovery has followed removal of blood clot. Fourteen cases have been recorded by M. Sadka.*

THE OPERATION OF LAMINECTOMY

Preparation of the patient.—In a clean case, such as a spinal tumour, little special preparation is required. The presence of any septic focus

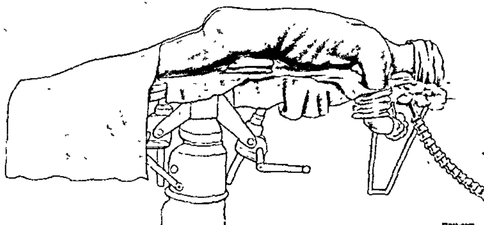


Fig. 178.—Position of patient for lumbar laminectomy.

Note the position of sandbags, so placed under the anterior superior iliac spines as to keep the abdomen off the table and let it hang free. In this way congestion of the veins in the lumbar part of the spinal canal is avoided.

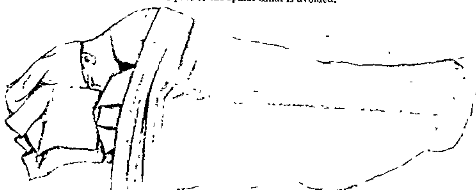


Fig. 179.—Position of patient for cervical laminectomy.

* *Med. Journ. of Australia*, 1953, ii, 669.

is, however, a grave danger; if the wound becomes infected from a neighbouring bedsore there is a possibility of cerebro-spinal meningitis, while septic infections elsewhere not only depress the powers of resistance, and thus add to the risk of operation, but also increase the post-operative dangers. It is thus most important that the operation be undertaken, if possible, before the onset of cystitis, bedsores, or bronchitis. Should pressure sores be present, every care must be taken to exclude them from the operation field, and thus lessen the possibility of infection, and the sulphonamides and penicillin should be administered both before and after the operation.

In the comparatively rare cases of compound injury calling for late laminectomy, the original wound will generally have healed soundly by the time operation is considered advisable, but if not, every effort should be made to diminish sepsis and limit the infection of the wound.

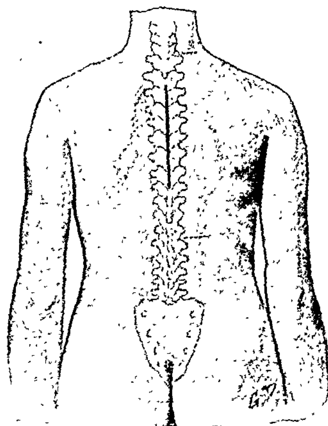


Fig. 180.—Skin-incision for an upper dorsal laminectomy.

Every care must be taken to cleanse surgically the skin of the back. The whole area should be carefully shaved so as to remove even the smallest hairs, then washed thoroughly with soap and water and gently swabbed with biniodide of mercury and finally spirit (70 per cent. containing ½ per cent. phenol). Apart from this, little should be done, and the administration of strong purgatives on the night before operation is strongly to be deprecated. The patient will have been kept in bed for two or three days previously, and should be given a full diet up to the night before, and taught to become accustomed to lying either fully or three-quarters prone, as this is the best position for nursing after the operation. On the morning of operation a cup of meat extract should be given some two hours before the anæsthetic is administered.

Anæsthetic.—Three-quarters of an hour before anæsthetization is begun, the patient is given a hypodermic injection of morphia, grain ¼, and atropine, grain $\frac{1}{100}$. Pentothal induction followed by intubation and nitrous oxide, oxygen, pethidine and trilene if required, have been

found satisfactory. During the operation the anæsthetist should record the pulse rate and systolic blood pressure at five-minute intervals so that any undue drop in blood pressure becomes at once apparent to the surgeon, and an infusion of blood or plasma may be begun, or the patient rested until the blood pressure rises again.

Technique.—The patient, being sufficiently under the influence of the anæsthetic, is gently rolled into the fully prone position (Figs. 178, 179),

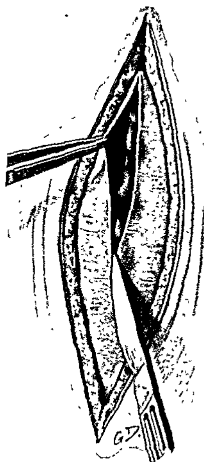


Fig. 181.—Laminectomy : incision of aponeurosis.

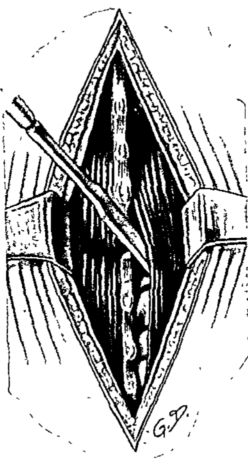


Fig. 182.—Laminectomy : separation of muscles from laminæ.

and sandbags, air-cushions or piled-up strips of sponge rubber are so placed that the operation field is supported and the spine made as convex as possible. For the thoracic region little support is required, as this portion of the spine is the most prominent. If the lesion is in the lumbar region it is generally necessary to have this portion of the body well supported, so that the lumbar concavity is as far as possible obliterated. For lesions in the cervical part of the column the head requires supporting in a slightly flexed position on some form of outrigger, such as is used for cerebellar operations. An operation table should be used which is fitted with an extension head-rest with shoulder supports to lift the chest clear of the table so that the thoracic respiratory movements are not impaired.

In the case of operations on the lumbar spine, sandbags should be placed under the anterior iliac spines so that pressure is taken off the abdomen. By this means congestion of the spinal veins is avoided, which is particularly desirable in operations for intervertebral disc lesions.

The surgeon stands on the left-hand side of the patient. The actual steps of the operation vary considerably in the hands of

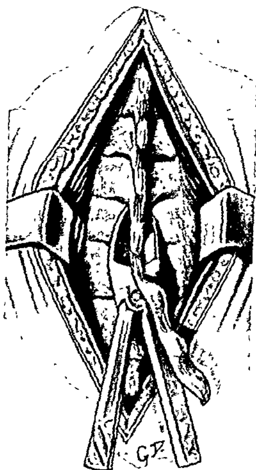


Fig. 183.—Laminectomy : removal of spinous processes with forceps.

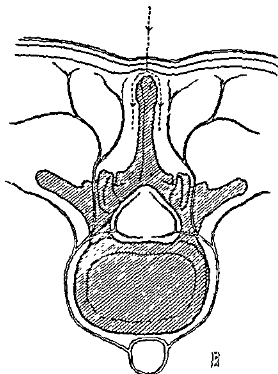


Fig. 184.—Diagram showing how, by keeping strictly to the midline and close to the bone, it is possible to turn aside the erector spinæ muscle mass out of the vertebral groove without dividing its blood supply.

individual operators, but these variations are, as a rule, only matters of detail which each has mastered in his own way. The first essential is to obtain a good view. The incision (Fig. 180) should be at least 6 to 8 in. long, and should have its centre opposite the anticipated site of the disease, in most cases this will have been determined precisely by myelography or other means (*see* p 450). The skin of the back has a comparatively poor blood supply when compared with that of the neck or the scalp. For this reason, and because it can be readily extended in either direction, if necessary, a straight midline incision is the most satisfactory and is to be preferred to the various "flap" types of exposure The first incision should pass through the subcutaneous tissue, and at this stage a few small subcutaneous vessels

require the application of hæmostats. Skin-protection cloths should now be attached to the wound-edges. The incision is deepened, the aponeurosis is divided and the deeper muscles are laid bare. (Figs. 181, 182.) An incision is now made through the erector spinæ muscle attachments to one side of the spinous processes and immediately against the bone, and with one sweep of the knife this incision is carried directly down to the laminæ This muscle separation is followed by considerable venous oozing which is controlled by introducing packs of hot moist gauze which are left *in situ* while a similar separation is carried out on the opposite side of the spinous processes. By keeping close to the bone, arterial bleeding is minimized (Fig 184.) The wound on this side is now packed with gauze, while the gauze from the first incision is removed to allow the separation of the muscles to be completed, a step for which cutting diathermy is helpful. A broad osteotome is also useful for this purpose (Fig. 185), and it is kept close to the bone so as to effect as bloodless a separation as possible. When the muscles have been completely separated, the greater part of the hæmorrhage will have ceased as the result of the gauze compression Oozing is further controlled by coagulating diathermy to bleeding points and by the introduction of self-retaining retractors. (Fig. 186.)

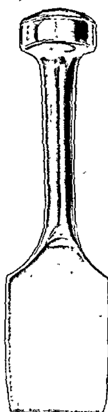


Fig. 185.—Author's pattern of broad bladed osteotome for turning the erector spinæ muscle mass out of the vertebral groove.

The spinous processes are now isolated and the interspinous ligaments at the limits of the wound are divided with scalpel and scissors. An appropriate number of spinous processes with their intervening ligaments are then removed with bone-cutting forceps. (Figs. 183 and 188) After removal of the spinous processes and ligaments, a clean smooth surface of bone, consisting of the posterior aspects of the laminæ, is left exposed in the field.

Of the various means adopted to gain an entry into the spinal canal, the simplest and the safest is to trephine one of the laminæ with a $\frac{3}{4}$-in. trephine (Fig. 187), from which the pin is removed, or by means of a burr to make an opening between two adjacent laminæ. To one experienced in the operation Horsley's or Trotter's forceps alone are usually sufficient to effect this entry. The lowest lamina is selected for the site of entry, as thereby the opening is made away from the site of the lesion, and the laminæ above are more readily removed by the surgeon working with his right hand. It is always advisable to make the opening away from the site of the lesion for, whatever its nature, there is otherwise a possibility that the posterior surface of the dura may be elevated against and adherent to the deep surface

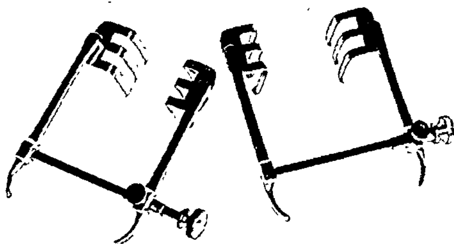


Fig. 186.—Author's pattern of self-retaining laminectomy retractors.

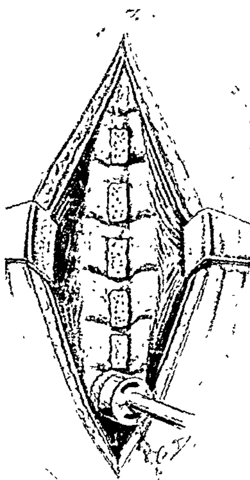


Fig. 187.—Laminectomy : trephining lowest lamina.

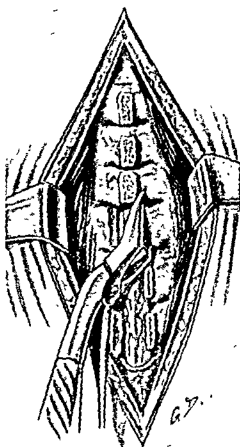


Fig. 188.—Laminectomy : method of dividing laminæ with forceps.

of the laminæ and thus be injured at the time of entry. In certain cases of injury an opening may already be found in the lamina; if so, it may be easier to enlarge this with a pair of small-bladed rongeur forceps. Some surgeons remove all the bone with laminectomy forceps such as those of Horsley; others prefer nibbling forceps or a combination of these instruments (Fig. 190). Chisels should not be used, owing to their concussing effect. The bone may be dense

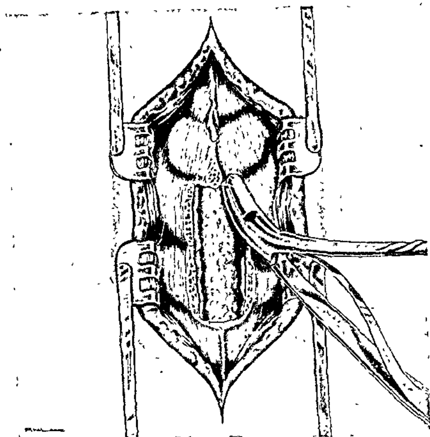


Fig. 189.—Laminectomy: removal of laminæ with nibbling forceps.

and firm, requiring considerable force to divide it. It must be remembered that this force must at all times be directed outwards and backwards, away from the dural tube and its contents. After an opening is made into the spinal canal further laminæ are easily removed with nibbling forceps, Horsley's separator or Adson's elevator (Fig. 191b) being used to clear the dura meter.

The greater part of the laminæ having been removed by the *cutting* forceps, the groove in the canal may be widened by means of guillotine forceps. (Figs. 191a, 192) These are so made that they cut upwards (i.e., *outwards*), and hence exert no pressure upon the cord. The remaining surface of the dura is *now carefully* cleaned of epidural fat and examined for any adhesions, scarring, or thickening. The surrounding surface of bone is also examined for evidence of injury, or for

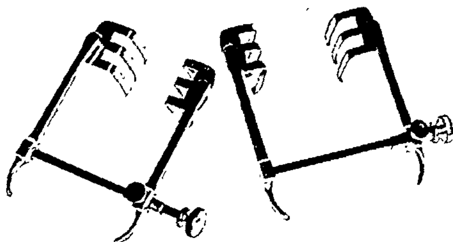


Fig. 186.—Author's pattern of self-retaining laminectomy retractors.

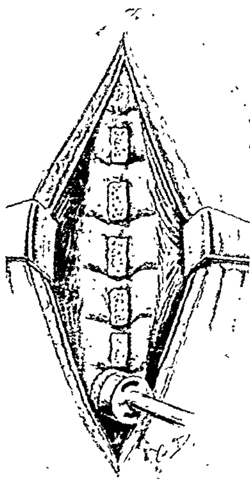


Fig. 187.—Laminectomy : trephining lowest lamina.

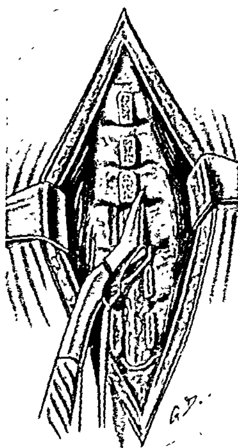


Fig. 188.—Laminectomy : method of dividing laminæ with forceps.

of the laminæ and thus be injured at the time of entry. In certain cases of injury an opening may already be found in the lamina; if so, it may be easier to enlarge this with a pair of small-bladed rongeur forceps. Some surgeons remove all the bone with laminectomy forceps such as those of Horsley; others prefer nibbling forceps or a combination of these instruments (Fig. 190). Chisels should not be used, owing to their concussing effect. The bone may be dense

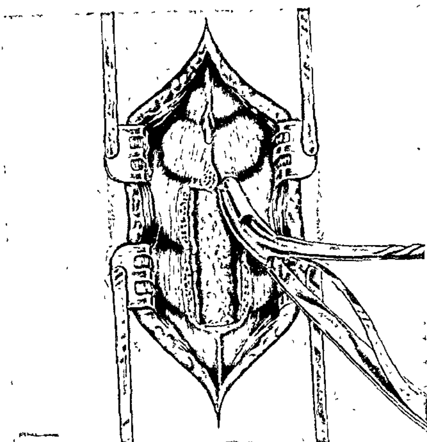


Fig. 189.—Laminectomy: removal of laminæ with nibbling forceps.

and firm, requiring considerable force to divide it. It must be remembered that this force must at all times be directed outwards and backwards, away from the dural tube and its contents. After an opening is made into the spinal canal further laminæ are easily removed with nibbling forceps, Horsley's separator or Adson's elevator (Fig. 191b) being used to clear the dura meter.

The greater part of the laminæ having been removed by the cutting forceps, the groove in the canal may be widened by means of guillotine forceps. (Figs. 191a, 192.) These are so made that they cut upwards (i.e., outwards), and hence exert no pressure upon the cord. The remaining surface of the dura is now carefully cleaned of epidural fat and examined for any adhesions, scarring, or thickening. The surrounding surface of bone is also examined for evidence of injury, or for

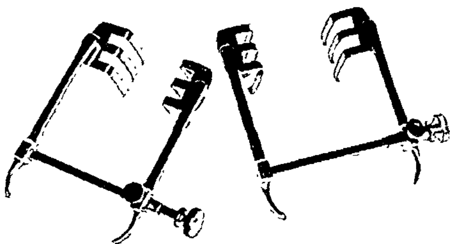


Fig. 186.—Author's pattern of self-retaining laminectomy retractors.

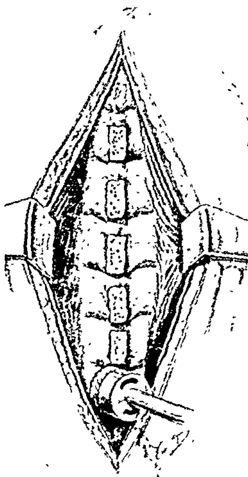


Fig. 187.—Laminectomy : trephining lowest lamina.

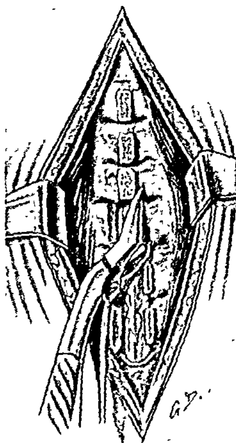


Fig. 188.—Laminectomy : method of dividing laminæ with forceps.

of the laminæ and thus be injured at the time of entry. In certain cases of injury an opening may already be found in the lamina; if so, it may be easier to enlarge this with a pair of small-bladed rongeur forceps. Some surgeons remove all the bone with laminectomy forceps such as those of Horsley; others prefer nibbling forceps or a combination of these instruments (Fig. 190). Chisels should not be used, owing to their concussing effect. The bone may be dense

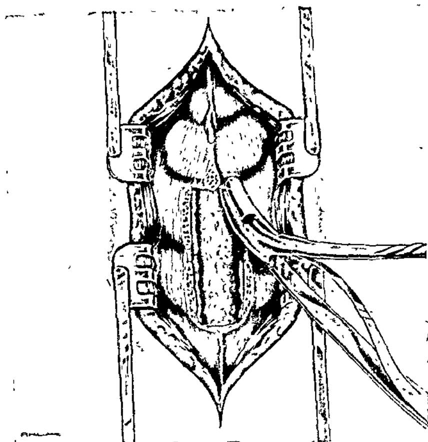


Fig. 189.—Laminectomy: removal of laminæ with nibbling forceps.

and firm, requiring considerable force to divide it. It must be remembered that this force must at all times be directed outwards and backwards, away from the dural tube and its contents. After an opening is made into the spinal canal further laminæ are easily removed with nibbling forceps, Horsley's separator or Adson's elevator (Fig. 191b) being used to clear the dura meter.

The greater part of the laminæ having been removed by the cutting forceps, the groove in the canal may be widened by means of guillotine forceps. (Figs. 191a, 192.) These are so made that they cut upwards (i e., outwards), and hence exert no pressure upon the cord. The remaining surface of the dura is now carefully cleaned of epidural fat and examined for any adhesions, scarring, or thickening. The surrounding surface of bone is also examined for evidence of injury, or for

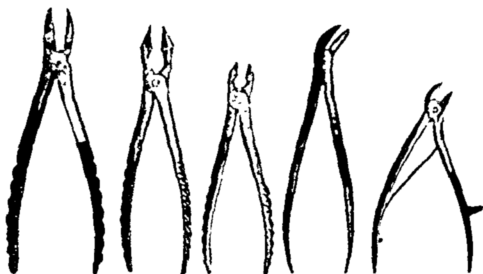


Fig. 190.—Forceps used for removing the spinous processes and laminæ.



Fig. 191a.—Guillotine forceps (Hudson's) for widening groove in laminæ.

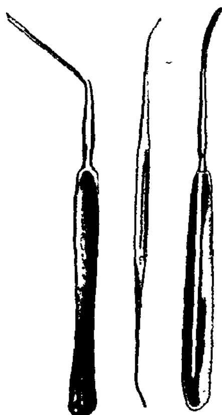


Fig. 191b.—Instruments for separating dura mater. On left is Horsley's "dura mater elevator", on the right Adson's.

primary or secondary neoplasm. At the same time, any local swelling of the dural tube which may give evidence of a tumour is looked for and pulsation or its absence are noted. It not uncommonly happens that pulsation of the dura is present above the lesion but absent below; hence, if there be no pulsation in the area of the dura which is laid bare, it is strong evidence that there is some abnormality above the level of the operation field, and it may be desirable to remove more

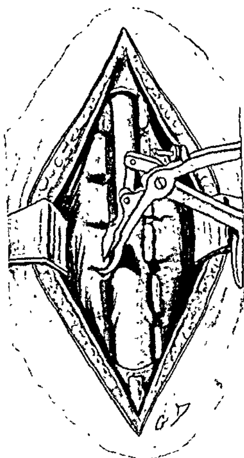


Fig. 192.—Laminectomy : method of widening groove in laminæ with guillotine forceps.

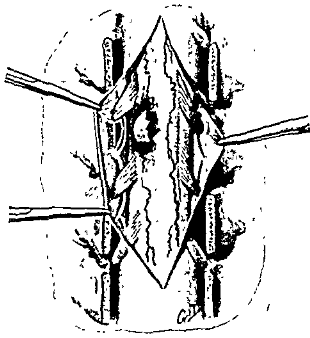


Fig. 193.—Foreign body embedded in surface of cord.

laminæ in the upper extremity of the wound. Gentle palpation of the dura may yield information, and a feeling of localized resistance may reveal the site of an intradural tumour.

Unless there is a definitely septic focus outside the dural tube, the next step consists in opening the dura. As with the bone, it is always better to commence the incision in a position remote from what is likely to be the situation of the lesion, so that, if the cord be adherent, it is in less danger of injury. As the dura is divided, sutures of fine silk, threaded on a small curved round-bodied needle supported in a needle-holder, are passed through the edges of the membrane, three or four along either side. These act as slings or guys for retracting the dura as it is opened. Care should be taken to



Fig. 195a.—Intrathecal extra-medullary meningioma removed from upper thoracic region of a married woman aged 42.

(Author's case) (Actual size)



Fig. 195b.—Vaculated intrathecal extra-medullary neurinoma removed from upper thoracic region of a labourer aged 32.

(Author's case) (Actual size)

performing the laminectomy, to work at all times away from the cord so that all concussing force is directed away from and never towards the cord. Although no tumour may be actually visible, it may be apparent that the cord is displaced or distorted; in such cases its rotation by gently drawing upon a slip of the dentate ligament may bring the tumour into view and allow of its removal. (Fig. 196.)

Removal of tumour. — Generally speaking, a neurinoma growing from the nerve-root is easily removed once its arachnoid covering is opened and the root to which it is attached divided. There is a vessel with the root which will require coagulation with the endothermy. In the case of the meningiomas which are in part adherent to the dura mater, it is advisable to remove the involved portion of the dura along with the tumour in order to avoid recurrence.







Fig. 196.—Exposure of anteriorly placed spinal cord tumour by rotation of the cord by means of a slip of the dentate ligament
(From Maingot's Techniques of British Surgery, Saunders)

It is sometimes helpful to exert traction on the tumour by multiple sutures of fine silk passed through it, particularly in the large tumours occasionally encountered in the cauda equina Such a tumour may be transfixed by a series of fine silk sutures, which are then grasped under an equal degree of tension by artery-forceps. Gentle traction is now made by pulling upon them, and the tumour lifted from its bed. (Fig. 197)

The condition of the cord must always be kept in mind in order to avoid undue retraction or displacement, and piecemeal removal of tumours is sometimes desirable to avoid this. It must again be emphasized that in all manipulations care must always be taken to work away from the cord.

Blood vessel tumours of the varicose variety which consist of anastomosing dilated pial vessels (varicocele of the spinal cord), if exposed at operation, are for the most part better left alone, attempts at ligating and separating vessels being ill advised and sometimes disastrous.

Intramedullary tumours.—Intramedullary tumours differ in type, some spinal gliomas growing rapidly, being richly supplied with blood vessels and not demarcated from their surroundings, while others are circumscribed and of slow growth. Tumours of the first variety do not readily lend themselves to surgical removal. Some are so soft, however, that they can be removed by suction, without damage to the cord,* others of the circumscribed variety may be dissected out and removed completely at a single stage,† while less demarcated tumours may be dealt with by the extrusion method of Elsberg.

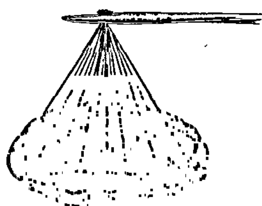


Fig. 197.—Removal of a tumour by the multiple thread method.

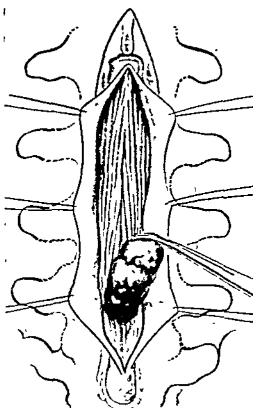


Fig. 198.—Removal of cauda equina tumour.
(*From Brit. Surg. Pract.*, *Butterworth*)

In this procedure a short vertical incision is made through the posterior column close to the midline. The tumour may now protrude but no attempt to remove it is made at this stage; the wound is closed

* H. Cushing, *Am. Journ. Dis. Child*, 1927, xxxiii, 551. † H. Cairns, *Brain*, 1931, liv, 2, 117.

and re-opened a week or ten days later, when it is found that the tumour is so far extruded from the substance of the cord as to permit of ready removal without damage to the cord itself.

Inoperable tumours.—The invasive gliomas of the cord may be quite irremovable short of resection of part of the spinal cord itself. Decompression and radiotherapy may slow down or even halt for a time the relentless march of symptoms produced by these tumours. They do not, however, metastasize and if there has been considerable destruction of the cord and interference with its functions, radical removal including a section of the cord may be advisable (spinal chordectomy). C. S. MacCarty and E. J. Kiefer* have recently reported a successful chordectomy in a man aged 25 with a malignant medullary astrocytoma for which they successfully removed the cord below the first thoracic segment.

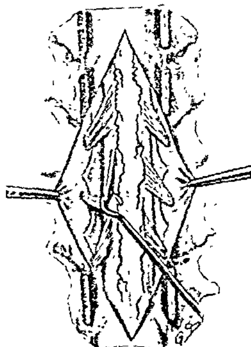


Fig. 200.—Posterior rhizotomy: elevation of posterior root preparatory to division.

Hydatids.—The cysts are extradural and usually multiple, and in removing them care must be taken not to rupture them for fear of dissemination. The cavities in the bone from which the cysts are removed may be swabbed with pure ether or formaldehyde $2\frac{1}{2}$ per cent. to destroy any free scolices, but the dural tube should not be swabbed with strong solutions of this substance, as a reactionary arachnoiditis, of which I have seen an example, may ensue.

Root section.—The roots which it is desired to divide having been identified, a blunt-hook is passed round them and care taken to separate the nerve bundles from the accompanying vessels (Fig. 200) Each root is then divided with a fine sharp knife. If there is bleeding from a divided vessel this should be arrested by endothermy, a silver clip or a fine silk ligature passed around it.

Chordotomy.—The level of section having been decided and the appropriate segment exposed by laminectomy, a slip of the dentate ligament is separated from its dural attachment and the cord slightly rotated. The appropriate (right or left) chordotomy knife (Fig. 201) having been selected, the point of the knife is entered immediately in

* Proc Staff Meet Mayo Clinic, 1949, xxiv, 108.

front of the site of attachment of the dentate ligament to the cord, and the antero-lateral tract is divided as shown in Fig. 202, care being taken to carry the incision well forwards but to avoid the anterior spinal artery. For posterior longitudinal cord section, a small sharp-pointed bistoury may be used to make the first incision in the cord (*see* p. 460). This is followed by a blunt-ended bistoury as the wound deepens, so as to avoid injury to the anterior median vessels. The type of section which has been made in cases of athetosis is shown in Fig. 175, p. 468.

Intervertebral disc lesions.—The herniated portion of the disc is usually easily removed extrathecally by gentle retraction of the dural tube and the overlying nerve-root, but in some cases, particularly in the cervical region, it is preferable to open the dura posteriorly, gently rotate and retract the cord (*see* above) and then expose the protruded cartilage by a second division of the dura anteriorly. The fibres of the posterior longitudinal ligament stretched over the projecting nodule are separated from it with a raspatory, and it is removed with pituitary rongeur or other suitable forceps assisted by curettage and suction. In some cases the nerve-root will be found elevated on a mound made by the extruded part of the disc which here forms a sequestrated mass which immediately comes away, as soon as the overlying and usually thinned longitudinal ligament is incised. Some surgeons have claimed to remove discs through small openings in the ligamenta subflava between the laminæ and without removing the spinous processes, but such a limited exposure which involves heavy retraction is to be avoided Laminectomy does not weaken the spine and by adequate exposure and gentle retraction of the erector spinæ muscle mass there is less aftermath in the form of back pain or muscle weakness.



Fig. 201.—Chordotomy knives for left and right antero-lateral section.

Closure of the wound.—Care should be taken to secure a bloodless field before beginning the closure. The dura should be closed with some interrupted fine silk sutures but if it has been necessary to remove part of it, e.g. in extirpating a meningioma, the defect may be made good by a piece of "gel foam" or one of the other fibrin products. The muscle masses should be carefully ap
passed on a curved round-bodied needle (Fi
be meticulous and accurate and followed
aponeurosis with fine interrupted silk sutures (Fig. 204). The skin is sutured with fine waxed-thread passed on straight cutting needles,

and a dry dressing is applied and kept in position with strips of elastic adhesive and a many-tailed binder.

Hemilaminectomy.—In this operation the deep muscles are separated from only one side of the neural arches, and the laminæ of this side only are removed. The spinous processes are retained, their bases being sawn or cut through by forceps in an oblique direction so as to leave them attached to the remaining part of the neural arch. The dura is divided longitudinally, thus exposing the cord and nerve-roots. The later steps and the *after-treatment are similar to those of a complete*

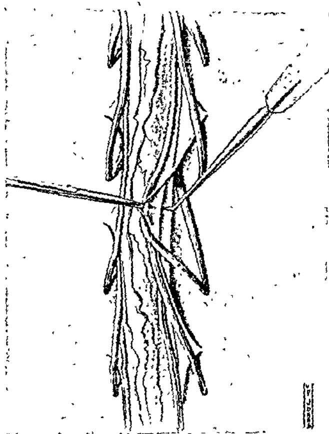


Fig. 202.—Chordotomy.

laminectomy. The operation has little to commend it over carefully performed laminectomy but is in favour with some surgeons.

Laminectomy, even if extensive, is not as a rule followed by any weakness in the spinal column except in the cervical region and then only if the laminæ have been divided very far out or if heavy retraction has interfered with the nerve supply of the post-vertebral muscles

After-treatment.—According to the patient's condition, intravenous saline, blood or plasma infusion may be required, either *during the* operation or on return to the ward, but such measures are not usually necessary. Tachycardia may be present after operation and may persist for some hours

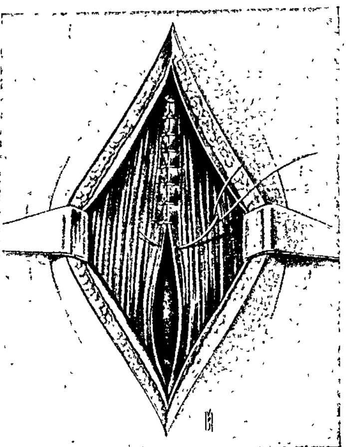


Fig. 203.—Laminectomy : suture of deep muscles.

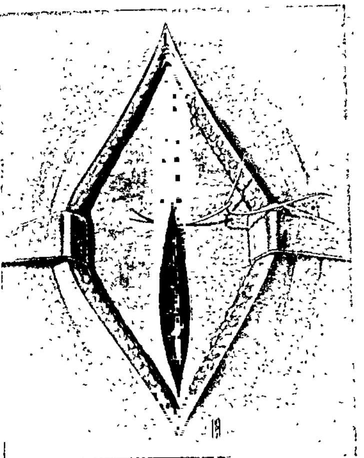


Fig. 204.—Laminectomy : suture of aponeurosis.

Acute post-operative dilatation of the stomach should be watched for and, should it arise, be treated by passing a stomach-tube and washing out the stomach and by changing the position of the patient. Failure to recognize this condition may be fatal. It is most likely to occur after high cervical operations, when it may possibly be the result of interference with descending autonomic impulses in the cord. Frequent vomiting of small quantities of dark fluid after a cervical laminectomy should at once raise a suspicion of acute gastric dilatation.

The patient is best nursed in the prone or semi-prone position, and if accustomed to this position for a few days before operation will not find it exacting afterwards. Unless there has been any inflammatory condition or there is serious discomfort from the wound it should not be disturbed for ten days.

Many patients are completely paralysed at the time of the operation, and it not infrequently happens that, even if the paralysis is incomplete before operation, it may, as a result of operative manipulation, however carefully carried out, be increased for a few days afterwards. The after-treatment is therefore associated with special nursing difficulties, and wherever possible a nurse should be chosen who has had experience of cases of this type.

In the care of the patients there are several details which demand attention. Because of diminished sensation and trophic changes, hot-water bottles are best avoided, and the patient kept warm by an electric cradle, which at the same time keeps the bedclothes away from the lower limbs. Great care must be given to the bladder and rectum. For several days or weeks catheterization may be required, and great care must be taken to maintain asepsis, especially if there be already a slight cystitis, for one of the chief post-operative dangers is the onset of pyelo-nephritis. If the retention of urine persist, it may be preferable to tie in a catheter, and establish tidal drainage. (*See also* care of the bladder in paraplegic cases, p. 442.) Should it be necessary to give a hypodermic injection, this should be administered in some portion of the body above the level of the lesion, for even a slight injury may give rise to trophic changes.

If the prone position is uncomfortable, the patient may be turned to one or other side, and the position should be frequently changed to prevent ill-effects from sustained pressure. For the first few days after operation the temperature may rise slightly, but it generally falls rapidly and must not alone be taken as an indication of the onset of sepsis. It may probably result from the liberation of cerebro-spinal fluid into the perineural tissues. For a time discomfort may be caused by voluntary or involuntary movements of the legs, which should therefore be supported by pillows; it may even be necessary to administer considerable doses of the bromides. Spasticity may increase at this stage, and massage should not be instituted until it lessens. In certain cases pain and discomfort may be caused by abdominal distension, especially if the lesion is above the mid-dorsal

region, but relief can generally be obtained by the administration of enemas and pituitary extract.

Rarely, there may be an escape of cerebro-spinal fluid from the wound, but this should not occur if the wound has been carefully closed in layers. Should cerebro-spinal fluid leak, the fistula usually closes spontaneously within the course of a week or two, during which time the utmost precautions should be taken to guard against infection, and gauze dressings wrung out of spirit (70 per cent. containing ½ per cent. phenol) should be used. It is very rarely necessary to employ operative measures to close such a fistula. While it persists systemic penicillin should be administered, great care taken with the dressings and the patient kept with the head low to reduce the pressure at the operation site. Spontaneous closure almost always occurs within a few weeks.*

In every case massage should be instituted when spasticity lessens, and should be given at short intervals for a prolonged period. By this means not only is nutrition improved but restoration of function accelerated

Pressure sores. *Prevention.*—Every care must be taken to prevent the appearance of these troublesome lesions. The effect of pressure-points must be minimized by a water bed, air-cushions or gauze pads. Cleanliness, frequent alteration of the patient's position and the avoidance of wet beds are essential. The skin must be kept dry, and at least twice daily treated by massaging lightly with methylated spirit followed by the application of finely powdered zinc stearate. The bed clothes should be kept off the lower limbs by a cradle.

Treatment.—If pressure sores (decubitus ulcers, bed sores) are present, deep collections of pus must be evacuated, while the position of the patient must be so adjusted as to remove all pressure from the necrosed area. With the return of conduction in the cord and of cutaneous sensibility these sores heal rapidly, but if there should be little or no improvement in the function of the cord and the state of the ulcers they may be excised and sutured or skin grafted according to their size and site.

The essentials of after-treatment may be summed up as follows:—

(*a*) to watch for acute gastric dilatation or other post-operative complication.

(*b*) to guard against pressure sores.

(*c*) to minimize the degree of infection in the urinary tract by due care of the bladder.

(*d*) to mitigate the discomfort of incontinence and make provision for adequate sleep.

Results.—The operation of laminectomy should be associated with but a low mortality, if cases are properly selected, with due

* J. F. Cooney and C. S. D[illegible]

consideration to the indications discussed and if a careful, bloodless, *gentle technique is followed with appropriate after-care.* Operative risk depends upon many factors, among which the age, condition, type and temperament of the patient are important, but one of the chief of which will always be the condition for which the operation is performed.

OPERATIONS FOR SPINA BIFIDA

Spina bifida is a congenital defect in the bony surroundings of the cord, and is often associated with a protrusion through the defect of the contents of the spinal canal. It is usually posterior, involving the laminæ, but may be anterior. Anterior spina bifida, which is extremely rare, may be seen as a protrusion of the membranes, or cord and membranes, through the vertebral bodies, which develop in two halves It very rarely occurs in the cervical region, when inspection through the patient's open mouth may show the posterior pharyngeal wall pushed forwards. It may also occur in the sacral hollow behind the rectum.

The posterior or commoner variety of spina bifida is most often seen in the lumbo-sacral region, least often in the cervical, and rarely in the thoracic region (Fig. 205). The deformity is estimated to occur once in every 1,000 births (Bland-Sutton), and about 80 per cent of these cases die within the first year of life The sex distribution is practically equal (John Fraser). Motor and sensory disturbances may be present in the lower extremities with loss of control over bladder and rectum.



Fig. 205 —Thoracic spina bifida (meningocele) successfully removed at operation

Varieties of spina bifida. (1) Spina bifida occulta.—*In this variety*, which is met with in the lumbo-sacral region, the laminal defect is small and the gap may be occupied by a fibrous-tissue plug to which the cord is adherent (membrana reuniens). There is usually *no defect apparent on clinical examination, but a dimple* (fossa coccygea), a tuft of hair or a lipoma may mark the site of the defect.

For a short time after coalescence of the neural folds to form the primitive neural tube, the embryonic cord and superficial epiblast remain in contact. Gradually they become separated by a mesodermal intrusion, which in spina bifida occulta, however, may be defective, in which case the primitive contact between skin structures and cord may persist as the membrana reuniens. During the period of growth, when the development in length of the cord lags behind that of the spinal canal so that at birth the cord terminates at the 3rd lumbar and at puberty at the 1st lumbar vertebra, the lower part of the cord may be under tension from the pull of the fibrous connecting plug and thus give rise to late symptoms. These usually appear between the ages of 8 and 14 and may take the form of incontinence or retention of urine, perforating ulcers on the feet or other trophic disturbances in the lower limbs.* I have operated upon a case in which late symptoms arose following an apparently successful operation for spina bifida early in life. The patient, a girl aged 23 with vascular and trophic lesions (ulcers, necrosis of bone), was relieved by division of a firm fibrous band which anchored the cauda equina to the scar tissue in the skin and passed through the dural tube. The cord terminated at the 3rd lumbar vertebra.

Spina bifida occulta is apparent on X-ray examination, which in fact often reveals unsuspected defects in the neural arches, usually in the lumbar or sacral regions, of patients who are quite free from symptoms and have no other indication that their vertebræ are in any way defective. Such symptomless cases do not of course require treatment.

(2) **Meningocele.**—There is an entire absence of nerve tissue within the sac, which usually has a narrow neck and contains only cerebro-spinal fluid.

(3) **Meningo-myelocele.**—This is the commonest of the gross forms of spina bifida, and the fundus of the sac consists of an area of granulation tissue which is composed of an undifferentiated portion of the cord. Von Recklinghausen described three areas characteristic of the appearances of a meningo-myelocele: (*a*) the area medullo-vasculosa (cord elements) just referred to; (*b*) the zona epithelio-serosa which immediately surrounds it, and (*c*) the zona dermatosa, an incomplete skin covering and the most peripheral area. (Fig. 206.)

(4) **Syringo-myelocele.**—The protrusion contains the dilated central canal (primitive neural tube) of the spinal cord.

(5) **Myelocele or partial rachischisis.**—This condition, in which the medullary groove remains in part unclosed, is incompatible with any length of postnatal life and is not amenable to surgical treatment.

Indications for and objects of operation.—The indications for operation in cases of spina bifida are (1) to prevent the onset of meningitis through rupture of the sac and leakage of cerebro-spinal fluid; (2) to remedy the deformity produced by certain types, e.g.,

* Sir John Bland Sutton first drew attention to the association of spina bifida occulta with neuro-vascular changes in the lower limbs in a paper, "Spina bifida occulta and its relation to ulcus perforans and pes varus," *Lancet*, 1887, ii, 4.

meningocele and some cases of meningo-myelocele and syringo-myelocele; (3) to relieve symptoms in spina bifida occulta with neural impairment. Operation is contra-indicated in those cases which show such severe involvement of the cord that the child is already or will soon be completely paraplegic, and in cases in which there is an advanced degree of hydrocephalus.

Opinions differ as to the best time to operate, but many surgeons, including myself, believe that *this should be as soon after birth as possible*. The newly born child is well adapted to the trauma of birth

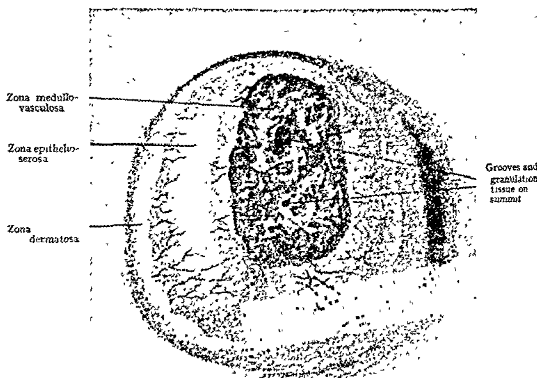


Fig. 206.—Three zones in a meningo-myelocele. (Bockenheimer)
(Reproduced by permission from Frazier, Surgery of the Brain and Spinal Cord, D. Appleton & Co., New York, 1918.)

and well able to accommodate itself to what may be described as an extension of this trauma in the form of a major operation. In practice it is found that these young babies stand operation well. Another reason for early operation is that post-operative hydrocephalus may be less likely to occur if the traction hypothesis of the cause of the Arnold-

ulceration are not a contra-indication if they are carefully isolated and not allowed to contaminate the operation field. These ulcerated areas, in which the coverings are very thin, indicate the imminence of cerebro-spinal fluid leakage and the desirability of urgent operation to prevent infection.

It has been suggested that the sac forms an absorbing mechanism comparable with the intracranial arachnoid villi (Penfield and Cole),* and that in any operation for spina bifida it should be retained, but corroborative evidence is lacking and most surgeons do not hesitate to sacrifice it while making every effort to preserve any nervous elements which may be associated with it. The particular operation performed must be influenced by the type of spina bifida and the degree of its development but, generally speaking, the essentials are the dissection of the sac so that it is free from its surroundings, and, after reducing its fluid content by tapping, either its removal or its infolding or plication so that it occupies the gap in the neural arches. The wound is then closed in layers using fascial flaps taken from the lumbar aponeurosis. No attempt is made to repair the bony defect (Fig. 207). Fine silk sutures are used throughout for the closure, first of any gap in the meninges left after dealing with the sac and next to approximate the overlapping aponeurotic flaps.

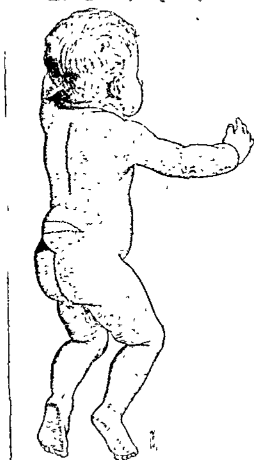


Fig. 207.—Diagram of incision for radical cure of spina bifida.

Technique.—General anæsthesia is best avoided, local infiltration of procain (1 per cent.) being used or, in the very young baby, no anæsthetic at all. The child is placed upon its face with the head low and precautions are taken to keep the frail little patient warm and to prevent shock. The skin incision is either transverse (Fig. 207) or longitudinal according to the shape of the sac, the nature of its coverings and the position of any areas of ulceration; but in the lumbar and lumbo-sacral regions the incision should always be a transverse one so as to keep the wound as far as possible from the intergluteal fold. Areas of ulceration are excised along with the redundant coverings after treatment with pure phenol or the actual cautery. The knife

* *Journ. Amer. Med. Assoc.*, 1932, xcviii, 454.

used for this purpose is discarded. The sac is now isolated by sharp dissection, freed from its surroundings and depressed so that it occupies the laminal defect by lying in the gap in the neural arches. If this is not possible the sac is opened, care being taken not to damage any neural contents, which must be freed and replaced in the vertebral canal; the distal portion of the sac is excised and a continuous fine silk or thread suture is used to close the part left attached. If nerve-roots have to be divided, care must be taken to ligate the accompanying

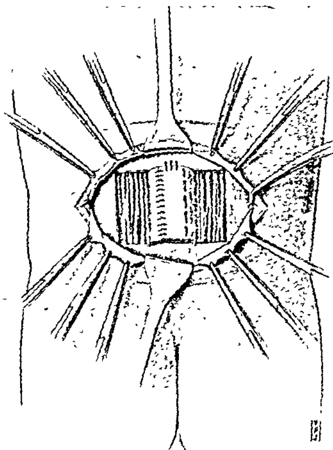


Fig. 208.—Overlapping aponeurotic flaps in the repair of spina bifida

blood-vessels, as fatal intrathecal hæmorrhage has occurred from neglect of this precaution (John Fraser). It must be remembered that in the meningo-myelocele the area medullo-vasculosa is none other than an undifferentiated portion of the cord and must be retained because it contains the ganglion cells. The next step is the further closure of the gap in the vertebral column, and although many devices have been employed, the simplest and most effective is the formation of overlapping musculo-fascial flaps, which are sutured by fine silk or thread. (Fig. 208) The skin-flaps, which have been fashioned in the first place and retracted during this time, are now approximated with fine waxed-thread interrupted sutures. Silver foil is placed over the wound and a compression bandage applied consisting of several

layers of gauze held in place by an elastic adhesive bandage. The child should be nursed head downwards for a few days to reduce the pressure of cerebro-spinal fluid on the wound. The child should be given a course of penicillin until the wound has healed and the danger of leakage no longer exists

Complications and results.—The chief complications of operation for spina bifida are infection leading to meningitis, which is usually fatal, and hydrocephalus, which is perhaps more likely to occur if the sac has been resected. A later complication is the appearance, usually at about puberty or early adolescence, of neurological features, the result of a drag on the relatively shortened cord by fibrous bands which unite it to the skin and for which operation may be required (p. 487). As might be expected, the results are best in cases of true meningocele and spina bifida occulta.

The treatment of spina bifida occulta which is giving rise to symptoms consists in an exploratory operation which has as its object the freeing of the cord. No treatment is indicated unless symptoms are present and when these appear they usually do so in late childhood or early puberty, so that operation is not indicated until then. The most frequent symptom is some disturbance in gait associated with maldevelopment of the feet or legs, the appearance of trophic ulcers on the feet or enuresis or incontinence.

Results.—In 18 of 21 cases operated upon by Ingraham and Lowry,* of Boston, good results were obtained. The commonest finding at operation was the presence of intradural and extradural lipomas.

Technique.—Transverse crescentic incisions are made to include the tuft of hair, the lipoma or the cutaneous depression (fossa coccygea) which indicates the peripheral attachment of the membrana reuniens. The fibrous membrane is dissected free from its parietal attachments and followed downwards through the defect in the neural arches. Some bone may have to be removed from the margin of the defective arches to give an adequate exposure The band is carefully separated from its neural attachments and the gap in the neural arch is closed, in so far as this is possible, by approximating the erector spinæ mass of either side, a series of interrupted sutures being used for the purpose. The aponeurosis is closed with fine silk interrupted sutures and the skin with interrupted waxed-thread stitches, and a dressing applied. In the surgery of spina bifida care must be taken to prevent infection, and prophylactic chemotherapy is advisable.

Diastometamyelia or Diplomyelia

This is a curious condition in which a bony mass, which may take the form of either a ridge or spur, projects backwards from the vertebral body through a gap in the cord, a part of which lies on either side of the protuberance. Diastometamyelia is the better term because the

* F D Ingraham and J J Lowry, Spina Bifida and Cranium Bifidum, Harvard Univ Press, 1943/44.

cord is not double as diplomyelia would imply but merely divided by the bony mass. Symptoms may be produced comparable with those seen in cases of spina bifida and become more pronounced as the child grows. There may be an abnormal stance or gait and sphincter disturbances. X-ray examination may disclose the bony ridge or spur and make the diagnosis obvious but in other cases myelography may be required to establish it. Laminectomy should be performed and the bony spur removed, great care being taken not to damage the cord. My attention was first drawn to the condition some 20 years ago by the late Professor Ernest Hey Groves of Bristol, who had operated on a case in a young adult. More recently, F. Ingraham, of Boston (Society of British Neurological Surgeons, Manchester, May 19th, 1950), has [illegible] teen cases in children whom he had [illegible] obtained benefit from the opera- [illegible] and in each case the lesion was in the lower thoracic or lumbar region of the spine. I have had one case, a woman aged 64, who had a bony column passing through the split spinal cord from the body to the neural arch of the 10th thoracic vertebra.

SPASTICITY

Spasticity in permanent paraplegia as may follow fracture dislocation with injury to the cord may be troublesome to the patient and various methods are adopted to relieve the painful spasms which occur in some cases. Relaxant drugs, operations such as anterior rhizotomy, posterior column tractotomy and the subarachnoid injection of alcohol have all been tried with varying degrees of success.

Recently selective chordectomy has been advocated and performed with success. For upper thoracic lesions excision of the cord from the lower thoracic segments to the conus has produced flaccidity and left the patient with an " automatic " bladder.*

* C S McCarty, 1954, *J Neurosurg*, xi, 539.

CHAPTER IX

OPERATIONS ON NERVES

By SIR HARRY PLATT

I. ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

Structural anatomy of nerve-trunks.—The conducting elements of a peripheral nerve-trunk are invested by a connective tissue framework which surrounds the entire trunk (the *epineurium*), encloses the individual bundles (the *perineurium*), and is continued into the interior of each bundle to form a delicate sheath around each nerve-fibre (the *endoneurium*). The nerve-fibres lie in parallel series, and are packed into bundles like a system of cables. Each fibre contains a slender fibril, which is the outgrowth of a nerve-cell situated either in the central nervous system, or in a ganglion of the autonomic nervous system. By this means the nerve-cells are brought into anatomical and physiological communication with distant end organs in motor, sensory, or secretory structures. Two distinct types of nerve-fibre can be distinguished :—*medullated* and *non-medullated.*

The medullated fibre is built up of three constituent elements :—(1) The axis cylinder (or axon), a central conducting fibril; (2) the medullary or myelin sheath, composed of lipoid substances contained in a neurokeratin framework; and (3) the neurilemma or sheath of Schwann, which is constricted at regular intervals, forming the nodes of Ranvier. Between each node is a nucleus lying in the myelin, and in close contact with the deeper aspect of the neurilemma.

The non-medullated fibre is characterized by the complete absence of myelin sheath.

Internal anatomy of nerve-trunks.—At one time it was held that the motor bundles supplying the different muscle groups occupied a constant position in the cross-section of a mixed nerve-trunk. It has been shown, however, that the individual nerve-bundles run a spiral course in the long axis of the nerve-trunk, so that the topographical arrangement changes repeatedly at different levels. In all the peripheral motor nerves there are intercommunications between bundles and groups of bundles. In the proximal part of a nerve-trunk the intraneural plexus provides a coarse grouping of fibres derived from various spinal segments. More distally, finer plexuses are formed which determine the ultimate arrangement of the fibres as they approach their levels of distribution.* In the repair of a clean-cut

* J. E. A. O'Connell, *Journ. Anat*, July, 1936, lxx, 468

division of a nerve without loss of substance, axial rotation of either *the proximal or distal stumps should be avoided.* But where there is destruction of a considerable length of a nerve-trunk, and where extensive freeing of the nerve above and below the injury is necessary, an accurate topographical suture is obviously impracticable

Degeneration and regeneration of nerve-fibres. Degeneration.—When a nerve-trunk is crushed or divided, the nerve-fibres distal to the point of injury or section undergo a process known as Wallerian degeneration. A similar reaction is seen also in a narrow zone in the proximal trunk in the immediate vicinity of the trauma. The degenerative change is a vital one, and affects all the constituent elements of the fibre.

The axis cylinders become swollen and, after undergoing disintegration, disappear entirely. The myelin sheath breaks up into a collection of globules which are ultimately carried away by the intraneural lymphatics. In the neurilemmal sheath the changes are proliferative; the nuclei stain more deeply, divide, and as a result the old sheaths become filled with new strands of a syncytial-like tissue. These neurilemmal tubules act as guides for the new axons

The process of degeneration involves the whole length of the distal nerve-trunk, and significant changes occur also in the various nerve-endings. Thus, in the motor end-plates the neuro-fibrils become fragmented and finally disappear The central ganglionic cells from which the degenerating axons arise also show a reaction to the stimulus of the peripheral injury. The cells become swollen, and exhibit a characteristic staining reaction known as chromatolysis These retrogressive manifestations are best marked when the nerve injury is severe, and particularly when the lesion is located in the proximal course of the nerve After a time the cells tend to return to the normal, but under certain circumstances recovery may be entirely absent.

Regeneration.—Degeneration is followed closely by regeneration, so that the two processes are advancing at the same time, the latter close on the heels of the former. All the evidence which is available from experimental, embryological and clinical sources goes to show that the appearance of new nerve-fibres in the degenerated peripheral stump is due solely to the downgrowth of axis cylinders from the central stump.

The earliest regenerative changes are well under way by the end of the first week after nerve section The axons in the central stump branch profusely, and on their growing ends are seen minute discs or bulbs of varying shape As the advancing axons reach the distal stump the bundles lose their orderly parallel arrangement, owing to the resistance offered by the healing connective tissue framework. Some fibres turn away from this barrier, others wander outside the limits of the cut surface of the nerve, and may be lost permanently. The majority of axons, however, penetrate the healing zone and enter the neurilemmal channels of the distal stump At this level a regular parallel arrangement reproducing the funicular pattern is once more

seen. The rate of the downward march of the growing axon has been estimated as one to two millimetres in twenty-four hours.* The new axon ultimately reaches the extreme periphery and, after a period of delay of unknown duration, grows into an end organ; thus the regenerative process achieves its object—the re-establishment of continuity between the central cell and the nerve terminal. Complete and perfect recovery of function depends on the multiple re-innervation of all end organs. The new axons do not appear to show a predilection for special channels in the peripheral stump, so that the end organs reached are matters of chance. All newly-formed axons are at first non-medullated. Later the process of myelination begins in the proximal stump and proceeds distally. The exact source of the new myelin sheath is unknown. The new primitive sheaths are formed from the proliferating neurilemma, and in this provision the central and peripheral segments of the nerve take an equal share.

The whole regeneration process is initiated and controlled by the central ganglionic cells. If the downgrowth of regenerating axons is blocked for a long time, the nerve-cells tend to lose their full power of dominating regeneration. Thus is seen the importance of the surgical repair of a nerve lesion within the first three months after the injury.

Operations on peripheral nerve-trunks fall into two main classes:—

1 **Reconstructive** procedures which aim at the restoration of conductivity in an injured nerve: e.g. *nerve suture; neurolysis; anastomosis; nerve-grafting.*

2. **Destructive** procedures which involve the deliberate sacrifice of conduction; e.g. *nerve blocking* (by crushing or injection); *neurotomy; neurectomy.* The operations in this class are employed either (*a*) for the relief of intractable pain and other irritative symptoms, or (*b*) to eliminate muscular spasm in certain non-progressive lesions of the central nervous system.

Types of Nerve Injury

Peripheral nerve injuries may be divided into two main groups, viz. (1) open and (2) closed The term "injury" is used here in a generic sense to include every type of abnormal mechanical influence to which the conducting elements of a nerve-trunk may be exposed.

1. **"Open" injuries.**—In this group the nerve injury is accompanied by an accidental wound.

2. **"Closed" injuries.**—In the absence of an external wound a nerve-trunk may sustain damage in the following circumstances:—
(i) *Contusion* or *laceration* due to a single severe blow from without, or to the initial displacement of a bony fragment in an associated fracture.
(ii) Continued *compression* or *friction;* the compressing agent may be (*a*) external to the nerve, e.g. cicatricial tissue, callus, or abnormal

* The rate of regeneration is influenced by the type and site of the injury, being greater in crush injuries and in the more proximal lesions

skeletal structure (cervical rib), an aneurysmal sac, a new growth, or (*b*) in the substance of the nerve-trunk itself, e.g. interstitial changes following hæmorrhage or inflammation, and the rare neoplasms of nerve-trunks; (*iii*) *Traction*; the majority of traction injuries involve the roots or trunks of the brachial plexus and occur either in the infant born after a difficult labour or in adults after falls on the shoulder.

II. PATHOLOGICAL CONSIDERATIONS

Healing of injured nerves. (1) After complete division.—When a nerve-trunk is divided completely, the cut ends retract within a short time. On the proximal end a bulb rapidly develops, composed



Fig. 209.—Transverse section of ulnar nerve in upper arm, 1¾in above line of suture

Specimen obtained from an amputated limb three years after surgical repair of the nerve. At this date there was no sign of restoration of conductivity. Interstitial fibrosis is seen extending around the individual nerve-fibres. (Dark staining areas.) (*Preparation made by Dr E A Linell*)

of proliferating connective tissue and budding nerve-fibres. The distal stump may become atrophic and pointed, or may acquire a fibrous cap. Under such conditions spontaneous regeneration on a large scale is impossible, although a few axons may occasionally bridge the gap and reach the distal trunk in which the classical Wallerian degeneration has occurred.

Where the nerve-trunk has been severely lacerated with a considerable loss of substance, the size of the gap and the connective tissue reaction in and around the area of the lesion constitute insuperable obstacles to regeneration. This fibrous tissue reaction is most

regenerative efforts. When the lesion extends over a considerable length of nerve, as in many traction injuries, few axis cylinders are able to find a way through the formidable intraneural scar.

Changes in other tissues.—Changes in structure are also found in the tissues to which the terminal nerve-fibres are distributed. These changes are due either *(a)* to *disuse*, which is an inevitable sequela of nerve-block, or *(b)* to *irritation* of sympathetic and sensory axons which remain intact. The disuse changes consist in muscular wasting, and retarded growth in the skin, hair, and nails. The changes dependent on irritation are usually described under the title "trophic",

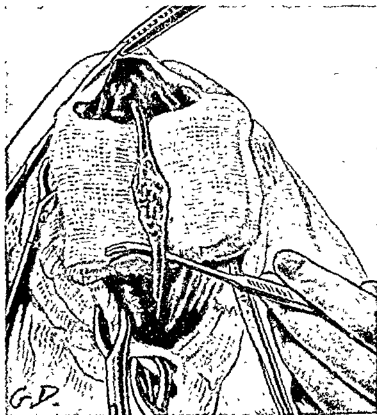


Fig. 211.—Lesion in continuity.
A typical nerve-spindle

and are characterized by a progressive fibrosis in muscle bellies, tendon sheaths and joint capsules, degenerative changes in the superficial tissues, and porosis in the bones of the hand or foot.

Types of lesion.—The histological changes in a nerve-trunk due to injury represent a composite picture to which the primary destruction, the early and late effects of wound sepsis, and the attempts at spontaneous repair have all contributed. Thus the various lesions commonly disclosed at operation have no exact anatomical or pathological basis. But a simple classification is useful to the surgeon, for without a definite schema the correlation of clinical and operative findings is impossible. For descriptive purposes it is sufficient to distinguish

three main types of lesion (Figs. 210, 211, 212): (*a*) complete division with a gap (complete nerve-trunk section); (*b*) complete division without a gap (complete axon section); (*c*) an intact nerve-trunk showing some localized alteration in calibre or consistency (incomplete axon section or transitory axon block). In this group the nerve-spindle (fusiform-neuroma) is the best-known lesion.

III. CLINICAL CONSIDERATIONS

It is unnecessary to describe in full detail the symptomatology of nerve injuries, but it should be agreed that the surgeon *must be competent to* undertake the clinical investigation of such patients, and that his province is more than that of a mere operator.

Clinical syndromes.—The state of conductivity in an injured nerve-trunk is best considered from the standpoint of the recognition

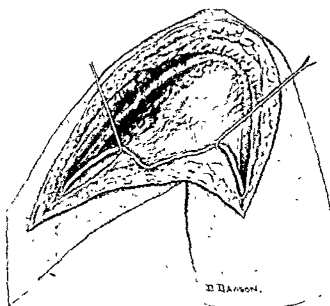


Fig. 212.—Exposure and mobilization of ulnar nerve at elbow and in forearm.
The nerve is seen reduced to an irregular attenuated cord.

of certain well-defined syndromes: (1) of complete interruption; (2) of incomplete interruption; (3) of irritation; and (4) of recovery.

1. Syndrome of complete interruption.—A complete nerve-block may be present at one stage in almost every type of lesion, the loss of conduction being either a passing phase or a permanent state: (*a*) *Motor signs.*—The muscle groups supplied by the injured nerve show a complete paralysis of the lower neuron type:—flaccidity, wasting, loss of deep reflexes, and certain alterations in the electrical responses (R.D.).* (*b*) *Sensory signs.*—Sensation is lost in an area representing the exclusive supply of the nerve. An accurate confirmation of the area of sensory loss is obtained by means of the sweat test (Guttman).

* In the reaction of degeneration (R.D.) the faradic response is absent; the galvanic response is sluggish and shows a polar reversal (A.C.C. > K.C.C.)

regenerative efforts. When the lesion extends over a considerable length of nerve, as in many traction injuries, few axis cylinders are able to find a way through the formidable intraneural scar.

Changes in other tissues.—Changes in structure are also found in the tissues to which the terminal nerve-fibres are distributed. These changes are due either (*a*) to *disuse*, which is an inevitable sequela of nerve-block, or (*b*) to *irritation* of sympathetic and sensory axons which remain intact. The disuse changes consist in muscular wasting, and retarded growth in the skin, hair, and nails The changes dependent on irritation are usually described under the title "trophic",

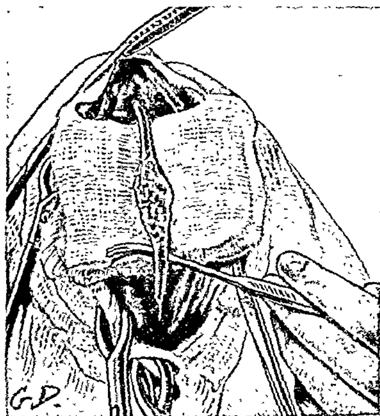


Fig 211 —Lesion in continuity.
A typical nerve-spindle

and are characterized by a progressive fibrosis in muscle bellies, tendon sheaths and joint capsules, degenerative changes in the superficial tissues, and porosis in the bones of the hand or foot.

Types of lesion.—The histological changes in a nerve-trunk due to injury represent a composite picture to which the primary destruction, the early and late effects of wound sepsis, and the attempts at spontaneous repair have all contributed. Thus the various lesions commonly disclosed at operation have no exact anatomical or pathological basis. But a simple classification is useful to the surgeon, for without a definite schema the correlation of clinical and operative findings is impossible. For descriptive purposes it is sufficient to distinguish

three main types of lesion (Figs. 210, 211, 212): (*a*) complete division with a gap (complete nerve-trunk section); (*b*) complete division without a gap (complete axon section); (*c*) an intact nerve-trunk showing some localized alteration in calibre or consistency (incomplete axon section or transitory axon block). In this group the nerve-spindle (fusiform-neuroma) is the best-known lesion.

III. CLINICAL CONSIDERATIONS

It is unnecessary to describe in full detail the symptomatology of nerve injuries, but it should be agreed that the surgeon must be competent to undertake the clinical investigation of such patients, and that his province is more than that of a mere operator.

Clinical syndromes.—The state of conductivity in an injured nerve-trunk is best considered from the standpoint of the recognition

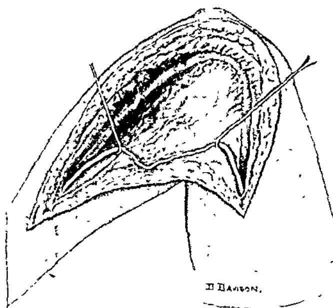


Fig. 212.—Exposure and mobilization of ulnar nerve at elbow and in forearm. The nerve is seen reduced to an irregular attenuated cord.

of certain well-defined syndromes: (1) of complete interruption; (2) of incomplete interruption; (3) of irritation; and (4) of recovery.

1. Syndrome of complete interruption.—A complete nerve-block may be present at one stage in almost every type of lesion, the loss of conduction being either a passing phase or a permanent state: (*a*) *Motor signs.*—The muscle groups supplied by the injured nerve show a complete paralysis of the lower neuron type:—flaccidity, wasting, loss of deep reflexes, and certain alterations in the electrical responses (R.D.).* (*b*) *Sensory signs.*—Sensation is lost in an area representing the exclusive supply of the nerve. An accurate confirmation of the area of sensory loss is obtained by means of the sweat test (Guttman).

* In the reaction of degeneration (R D) the faradic response is absent, the galvanic response is sluggish and shows a polar reversal (A C C. > K C.C)

It is customary to record sensory loss in terms of three types of stimulus :—(i) epicritic loss, embracing the absence of response to the lightest touch, inability to recognize the finer variations in temperature, and failure to localize accurately the point of a stimulus ; *(ii) protopathic* loss (analgesia), over a less extensive and often ill-defined zone where painful stimuli and the extremes of temperature are unrecognized ; *(iii)* deep loss, characterized by an absence of those afferent impulses from fasciæ, muscles, tendons, and joints which determine the recognition of pressure touch, pressure pain, and their localization. The area of deep anæsthesia is usually much smaller than the area of analgesia. *(c) Vasomotor, secretory, and trophic signs.*—These are inconspicuous in the syndrome of complete block, but the skin may be cold, pale or dusky, and slight retraction of muscles and fibrous changes in the joint capsules may be seen. *(d)* The *injured nerve-trunk* is usually painless on direct palpation.

2. **Syndrome of incomplete interruption.**—The syndrome of partial nerve-block may represent a fully-matured lesion for an indefinite period. Considerable variations may be seen, owing to the presence of conducting nerve-bundles. (1) A characteristic picture is often seen in the earlier stages of *compression* or friction lesions consisting of *(a)* increasing paralysis and muscular atrophy ; *(b)* a dissociated sensory loss with the analgesia (protopathic area) greater than the area of tactile (epicritic) anæsthesia.* (2) One variation is the "*distal*" syndrome in which the proximal muscles are active but there is palsy of the distal muscles combined with more or less complete sensory loss. The injured nerve may be thickened and tender.

3. **Syndrome of irritation (traumatic neuritis).**—This has long been recognized as a striking picture in gunshot injuries, and is also seen in some of the nerve injuries of civil life. The signs of partial block are combined with, and often overshadowed by, trophic and sensory phenomena. The latter consist of pain, hyperæsthesia, tenderness of the nerve-trunk, cyanosis, glossy skin, brittle and stunted nails, and rigid contractures. In the most severe form of the irritation syndrome known as *causalgia*, which is seen more especially in gunshot injuries of the median and sciatic nerves, the symptoms are of dramatic intensity. Agonizing pain of a bursting or burning type is felt in the hand or foot, and is enhanced by all forms of emotional or physical stimuli.†

4. **Syndrome of recovery.**—Tone appears in the wasted muscles which become unduly sensitive. Later there is a return of voluntary power accompanied or preceded by a return of faradic excitability. (An earlier hint of recovery can be obtained from electromyographic testing.) After complete nerve-block, sensation reappears in overlapping stages:—recovery of deep cutaneous pain, superficial cutaneous pain, coarse touch, and finally light touch.

* Stopford, *Brit. Med. Journ.*, June 19, 1926, i, 1028.

† It is now held that causalgic manifestations are the result of an artificial synapse between the sympathetic and afferent nerve fibres in the injured nerve trunk.

Indications for Operation

When a diagnosis of injury to an important nerve-trunk has been made, a further problem at once arises. It is necessary to decide whether spontaneous recovery is likely to occur, or whether the lesion will demand operative repair. In nerve injuries accompanied by an open wound, the damaged nerve may be available for direct inspection during an emergency operation. But in subcutaneous injuries the extent of the lesion must usually be assessed *on clinical evidence alone.* This often means a period of observation lasting from three to six months from the date of the injury. If a serious lesion is suspected, it is reasonable to explore the nerve early, and to deal with it in accordance with the findings. In a certain number of injuries thus explored for diagnostic purposes the lesion will require no form of repair, but in competent hands no harm will result from the exposure. In the graver type of the irritation syndrome early operation is always advisable.

IV. OPERATIONS FOR NERVE INJURIES

General Considerations

It is customary to distinguish between the *primary* and *secondary* exploration of an injured nerve.

Primary exploration is rarely practised except where the nerve injury is accompanied by an external wound. In civil injuries, which are commonly produced by the penetration of sharp instruments, fragments of glass and the like, the wound may be comparatively "clean". Under such conditions the immediate suture of a divided nerve is likely to be followed by uninterrupted recovery. But where the wound is infected from the outset, recovery after primary nerve-suture is problematical, for sepsis is always inimical to regeneration. In infected wounds it is often wise to repair less vulnerable structures (e.g. divided tendons), and to postpone repair of the nerve until a later stage. Meanwhile, the ends should be approximated by one or two sheath sutures, and the nerve-trunk shut off from contact with the infected and injured area. When the wound has soundly healed, the nerve should be re-explored and repair completed. These considerations apply with particular force to gunshot wounds, in which gross contamination is the rule.

Secondary explorations are undertaken (*a*) after the healing of an accidental wound, or (*b*) in "closed" or subcutaneous nerve injuries produced by contusion, compression, or traction. In the former a probationary period of from three to six weeks should be allowed after final healing in order to avoid the risk of a recrudescence of infection. During this time the nutrition of the injured part should be maintained and improved by appropriate physiotherapeutic treatment. Skin-scars should be softened and loosened, and stiffened joints mobilized. Such obstacles to free mobility not only add to the difficulty of the

exposure of the nerve, but may render the lesion irreparable. The operation will be less difficult if attention is also paid to the following preliminary details—(*a*) A wide skin area should be sterilized, which should include the whole limb and often part of the trunk; (*b*) suitable splints should be assembled which have already been fitted to the limb in the position likely to be adopted when the operation is completed; (*c*) the correct position of the patient and limb on the operation table should be tried before the sterile sheets are in place. Where an alteration in position is necessary in the closing stages of the operation, the arrangements should allow the change to be made with the minimum disturbance. The success of the operation may depend on careful pre-operative rehearsal. Many of the operations for extensive nerve injuries are exceedingly difficult and tedious.

Exploration of an Injured Nerve

The operation comprises the following steps:—

(I) **The skin incision,** which is made either over the course of the nerve or in the form of a flap.

(II) **Exposure of the nerve-trunk.**—The nerve is usually displayed after opening up a suitable intermuscular space, and is sought for *first above and then below the level of the lesion.* The trunk is freed from its bed by gentle dissection, care being taken to avoid injury to the sheath.

(III) **Electrical stimulation.**—If the *nerve-trunk* is intact the response to direct excitation is noted A suitable sterilized electrode (bipolar or unipolar) with long cords connected to a faradic coil, is used. If the unipolar method is adopted, the " pad " electrode should be placed in contact with the patient's body before the operation begins.

In a nerve injury of more than two weeks' standing, a response to the faradic current indicates continuity of nerve-fibres through the lesion. A negative response within six months confirms the clinical supposition that actual degeneration of nerve-fibres has occurred. In a nerve-trunk explored many months beyond the normal limits of the spontaneous regeneration period, a lack of response suggests the existence of a *permanent* block to regeneration But a positive response may occasionally be elicited during an operation when the syndrome of complete nerve-block has existed for a long time and pre-operative electrical tests have shown an absent faradic reaction in the affected muscles It is believed that regenerated sensory fibres which have grown down motor-sheaths in the distal trunk may acquire connections with motor end-organs, and later react to direct faradic stimulation In addition to testing conduction in the injured nerve-trunk itself, the faradic stimulus is useful in the identification (*a*) of neighbouring nerve-trunks in the operation field, and (*b*) of motor branches arising proximal to the lesion.

(IV) **Exposure of the lesion.**—At this stage the operation difficulties usually arise, owing to the obliteration of landmarks by scar tissue. When the area of the lesion is first attacked it is wise to assume that the block of the scar tissue contains intact nerve-bundles, however unpromising its appearance. A nerve-trunk, much distorted and thickened but capable of future conduction, may often be disentangled from a dense scar. For this reason all incisions should be made in the long axis of the nerve during the dissection.

(V) **Treatment of the lesion.**—The method adopted will depend on the extent of the lesion and its effect on the conducting powers of the nerve.

(1) **Nerve-block.**—Where there is a complete solution of continuity, the operation of *end-to-end suture* alone will suffice. Where the nerve-trunk shows insignificant macroscopical changes, as in many of the subcutaneous injuries, freeing of the nerve, removal of the compressing agent, or displacement of the nerve to a new bed is the appropriate measure—i.e. the operation of *neurolysis*.

In many of the graver lesions which show an apparent naked-eye continuity, the choice has to be made between *resection* followed by *suture*, and the conservative operation of *neurolysis*. No hard and fast rules can be laid down. The surgeon must attempt to estimate the relative amount of scar and intact nerve-fibres. Useful information may sometimes be obtained by incising the nerve-sheath in a longitudinal direction and inspecting the contained bundles. When the cicatricial tissue predominates, regeneration on a large scale after neurolysis is impossible. In long-standing nerve injuries presenting such a condition of affairs, resection is often indicated, but a cautious attitude should be adopted towards more *recent* injuries, in which neurolysis should be given a trial. If recovery does not follow neurolysis the nerve should be re-explored without undue delay, and the area of the lesion resected. Where the clinical signs point to partial interruption of conduction, the choice between resection and neurolysis is often determined by the relative importance of the motor and sensory functions subserved by the injured nerve. Thus, in the *median nerve* it is reasonable to sacrifice intact *motor* bundles when the obstacles to the regeneration of sensory fibres are admittedly insuperable. In the *ulnar nerve* the conditions are reversed; the sensory supply is of little value compared with the function of the intrinsic muscles of the hand.

(2) **Irritation syndrome.**—So far the nerve lesion has been considered merely in relation to the loss of conduction and the problem of its restoration by operation But in certain nerve injuries the clinical signs are mainly those of *irritation*. Many of the milder types of traumatic neuritis respond well to conservative treatment but, if operation becomes advisable, neurolysis is the procedure of choice. In the special form of the irritation syndrome known as *causalgia*, the affected nerve should always be explored. In this condition, and in

other severe forms of traumatic neuritis, conduction must be completely abolished. This may be attained in two ways :—

(a) *Intraneural injection of alcohol.*—It has been claimed that 60 per cent. alcohol spares the motor-fibres and merely produces a temporary block in the sensory bundles of a mixed nerve (Sicard). But if the sensory block is to be truly effective, the risk of motor palsy must always be faced. In causalgia, complete obliteration is justifiable, for nothing less will relieve the intolerable sensory symptoms. The injection technique is simple. A fine hypodermic needle is thrust into the nerve-trunk above the level of the lesion, and the complete cross-section infiltrated with absolute alcohol. The nerve becomes distended in the region of the injection and assumes a dead-white appearance.
(b) *Resection and end-to-end suture.*—Resection of the lesion followed by end-to-end suture is a more certain and accurate method of producing complete nerve-block, and is to be recommended for causalgia.
(c) *Sympathectomy.*—The operation of *periarterial sympathectomy* popularized by Leriche has by common consent been abandoned. In severe cases of causalgia after a diagnostic procaine block of the appropriate ganglia, *ganglionectomy* is now regarded as the treatment of choice.

End-to-End Suture

Difficulties.—Where considerable loss of nerve substance has occurred, certain technical manœuvres which facilitate end-to-end apposition must be utilized: (a) *The nerve-trunk* should be exposed and mobilized as widely as possible. A nerve-trunk can and should where needed be mobilized over a length of many inches. This can be done with impunity, as the intraneural vascular supply alone is sufficient to maintain adequate nutrition.* (b) *The nerve-trunk* should be fully relaxed by an appropriate change in the position of the limb.

Position of Relaxation of Main Nerve-Trunks

Nerve	Position
Median nerve	Upper arm close to chest ; elbow and wrist fully flexed.
Musculo-spiral nerve	Upper arm close to chest , elbow fully flexed ; wrist dorsiflexed.
Ulnar nerve—*if nerve is left behind* the internal condyle.	Upper arm close to chest ; elbow extended ; wrist flexed
Ulnar nerve—*if nerve is displaced in* front of the epicondyle	Upper arm close to chest ; elbow and wrist fully flexed
Brachial plexus	Head approximated to shoulder ; arm elevated, or close to chest
Sciatic nerve and its main divisions	Hip hyperextended ; knee fully flexed.

* Torraca, *Chirurg Degli Organi di Movimento*, July, 1920, iv, 279.

(c) *Motor branches* arising proximal to the lesion, which always tend [illegible] up from within the nerve- [illegible] one with extreme delicacy the small twigs suffer no permanent injury. (d) *Displacement of the nerve* to a new bed in order to shorten *its course, e.g. transposition* of the ulnar nerve to the front of the elbow. If, in spite of such efforts, end-to-end apposition is still unattainable, there remain two alternatives. (e) *The two-stage operation.*—A procedure of doubtful value. At the *first* exploration the untrimmed nerve-stumps are approximated as closely as possible, and anchored by a stout suture with the limb in the position which affords the maximum relaxation. The wound is then closed. A few days later gradual stretching of the flexed joint is begun, and completed by the end of six weeks. The steady traction tends to elongate the nerve-trunk, and so diminish the gap. In the *second* stage the wound is re-opened and an attempt made to complete the suture. (f) *Bone shortening.*—This operation has been practised both in the forearm and in the lower limb. It is a useful method of facilitating repair of the *musculo-spiral nerve* when accompanied by an ununited fracture of the *humerus.*

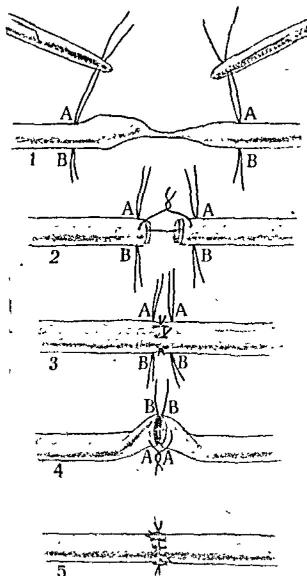


Fig 213.—Technique of nerve-suture. Shows the various stages in resection and suture. Note the guide sutures and the approximation of the sheath by *interrupted stitches.*

Suture technique. (Fig. 213.) (a) Trimming the nerve-ends.—The essence of nerve-suture is to bring normal bundles in the proximal stump into apposition with normal bundles in the distal stump. In a complete anatomical lesion a preliminary trimming of the nerve-bulb is necessary ; where pseudo-continuity is present the injured segment must be resected. On the trimmed surfaces there should be no

was introduced.* In this procedure both the central and distal ends of the injured nerve were implanted some little distance apart into the receiving nerve, which provides, as it were, a living bridge.

Under experimental conditions the feasibility of restoring function by nerve-crossing has been repeatedly proved, but when this operation is applied to the treatment of nerve injuries in the human subject it is attended by obvious disadvantages. In the first place, the reinforcing nerve must be deliberately injured, although such a sacrifice may conceivably be justifiable. It has been claimed, however, that the disturbance of conduction is negligible when double implantation is carried out with great delicac [illegible]
operation, a limited number [illegible]
sheaths of the distal trunk ; [illegible]
end organs. But when due allowance has been made for such imperfections, the operation of nerve-crossing has achieved some degree of success as a method of indirect nerve repair in certain situations. Its scope may be briefly considered in relation to (i) the facial nerve; (ii) the brachial plexus, and (iii) the larger nerves of the upper limb.

Facial nerve.—The first nerve-crossing for facial palsy was done in 1895 (Drobnik), the *spinal accessory* being chosen as the reinforcing nerve. The operation was practised with occasional success for many years, but later was supplanted by *facio-hypoglossal* anastomosis, which involved the lesser sacrifice of the relatively unimportant lingual muscles. *Facio-glossopharyngeal* anastomosis by the end-to-end method has also been tried, and is regarded by some authorities as a definite advance in technique.† *See* Operations on the Facial Nerve (p. 533).

Brachial plexus.—Experimental nerve-crossing after the division of *two* or more brachial plexus roots in monkeys has been followed by genuine restoration of function (Kennedy). In the small proportion of complicated plexus injuries where end-to-end suture is feasible after resection of the block, the distal trunks often outnumber the proximal trunks. In such circumstances the operation of repair becomes, in part, at least, an unavoidable experiment in nerve-crossing.

Upper limb nerve-trunks.—There are many examples on record where incomplete peripheral anastomosis between the *median* and *ulnar* nerves has resulted in permanent damage to the recipient nerve with no compensatory restoration of function in the injured nerve. The operation therefore cannot be recommended. At the present time all forms of nerve-crossing in the upper limb are *sub judice*, and are best avoided.

2. Alternative operations.—The operations which fall under this heading are designed either (1) to restore lost motor function, or (2) to eliminate a painful, useless or dangerous limb. The available reconstructive procedures have long been practised in the residual paralyses of anterior poliomyelitis. In irreparable nerve injuries the following operations may be used with advantage :—

* Ballance, *Brit. Journ. Surg.*, 1926, xiii, 51.
† Ballance, *Brit. Med Journ*, Aug. 30, 1924, ii, 349

(*a*) **Tendon-transplantation.**—In lesions of the *musculo-spiral* (and posterior interosseous), transplantation of the pronator radii teres into the radial extensors, the flexor carpi radialis into the short thumb extensors, and the flexor carpi ulnaris into the long thumb extensors and extensors of the fingers gives striking results. In *median* lesions, opposition of the thumb may be restored by an appropriate tendon transplantation (*see* p. 151).

(*b*) **Arthrodesis**, to stabilize a flail joint accompanying an extensive palsy. The operation is chiefly practised on the shoulder joint and smaller joints of the foot (*see* p. 88).

(*c*) **Amputation** is chiefly called for in old sciatic injuries with pain and intractable ulceration of the foot (*see* p. 192).

Operative Treatment of Tumours of Peripheral Nerve-Trunks

Simple tumours (neuro-fibromata or neuro-myxomata) when arising from the outermost connective tissue envelope are easily removed without damage to any conducting elements. Such tumours developing in the interior of the nerve-trunk present a more difficult problem, but by careful and delicate dissection it is possible to enucleate an encapsulated tumour in such a situation, and at the same time to preserve most, if not all, the displaced and overstretched nerve bundles. The *malignant* tumours of peripheral nerve-trunks (neuro-sarcomata or neuro-epitheliomata) demand radical treatment, and a long length of nerve-trunk should be resected without hesitation. Local recurrence after such a procedure calls for amputation.

V. OPERATIONS ON INDIVIDUAL NERVE-TRUNKS

Operations on the Brachial Plexus

Indications.—The more important lesions for which operative exploration may be required are: (*a*) Traction injuries of the supraclavicular trunks (birth palsy—Erb-Duchenne; traction lesions of the adult); (*b*) compression or friction neuritis of the *lower* trunks associated with a cervical rib; (*c*) penetrating injuries; accidental or gunshot wounds involving the supraclavicular or infraclavicular regions where the great vessels have escaped immediate serious damage; (*d*) contusion of the infraclavicular trunks, complicating shoulder-joint dislocations, and injuries of the upper end of the humerus or glenoid fossa.

Special anatomical features.—(1) The supraclavicular nerve-trunks are invested by a fascial sheath which is peculiarly dense under normal conditions, and which, when invaded by scar tissue, makes the disentanglement of the nerves an exceedingly difficult feat.

(2) The two scalene muscles are the main guides to the upper part of the plexus.

(3) Certain of the smaller primary branches of the cervical or brachial

plexus are important anatomical landmarks. These are: the nerve to the rhomboids, the nerve of Bell, and the phrenic nerve.

(4) The suprascapular nerve, which is *comparatively large* and easily exposed, when traced upwards enables the surgeon to display the junction of the 5th and 6th cervical anterior primary divisions.

(5) To expose effectively the lowest trunk of the brachial plexus, the subclavian artery must be freed by delicate dissection and gently

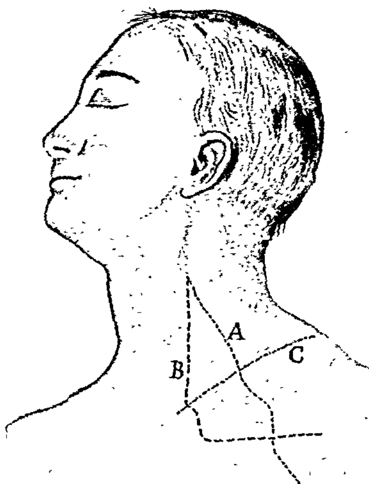


Fig. 214.—Exploration of brachial plexus. Shows three types of skin incision.

retracted. In this region the relation of the structures to the first rib and to the dome of the pleura must be recalled.

(6) In the more extensive lesions in which *end-to-end suture* of several trunks is necessary, division of the clavicle is an essential step.

Preparations for operation.—(1) In the graver traction or penetrating lesions where end-to-end suture is likely to be required, *post-operative relaxation* of the sutured nerve-trunks must be provided for. This will mean approximation of the head to the shoulder, with the arm abducted or even fully elevated. A moulded splint or plaster of Paris shell should be constructed in advance. (2) The skin preparation should include the

whole neck (the lower occipital region should be shaved), half the upper chest, and the upper limb as far as the finger-tips. (3) As it may be necessary to divide the clavicle, drills, saws and bone-suture material should be included in the armamentarium.

Position on the operating table.—The patient is placed on his back, with a small sandbag between the shoulder-blades. The arm on the operation side is pulled down close to the body, and the head tilted towards the opposite shoulder. The anæsthetist should use one of the recognized "long distance" methods of administration which allows the head of the patient to be covered completely by sterile towels.

Skin incision.—The choice is offered of :—

(*a*) A *flap* with a vertical limb skirting the posterior border of the sterno-mastoid in the lower half, and a horizontal limb placed in the infraclavicular hollow (Stiles). (Fig. 214B.) For exposure of the infraclavicular plexus an additional incision is carried downwards over the anterior fold of the axilla.

(*b*) A *single* oblique cut, beginning at the posterior border of the sterno-mastoid and ending below over the coracoid. (Fig. 214A.)

(*c*) A *transverse* incision across the root of the neck at right angles to the line of the plexus trunks (A. S. Taylor). (Fig. 214C.) This gives admirable access.

Exposure of the supraclavicular trunks and branches.—The various stages may be described in sequence :—

I. The skin-flap is reflected and the platysma divided along the same line. The lateral border of the sterno-mastoid is defined and the deep fascia divided above the clavicle. This outlines the supraclavicular pad of fat and lymphatic glands which should be carefully turned aside and preserved. The external jugular vein will now require ligature, and the omo-hyoid muscle, which also bars the way to the nerve-trunks, should be divided. With adequate retraction of the sterno-mastoid, the anterior and middle scalene muscles are clearly displayed, and between them the *upper* and *middle* trunks of the plexus appear enclosed in a common fascial sheath The latter is often peculiarly tough and is closely fixed to the sheath of the scalenus medius.

II. *The upper trunk* is short and divides at Erb's point into three branches: (*a*) the suprascapular nerve ; (*b*) the branch to the outer cord , and (*c*) a branch to the posterior cord. The first-named, when traced upwards, is a useful guide to the main trunk. If necessary, the anterior primary divisions of the 5th and 6th cervical nerves may be followed up to the level of the cervical transverse processes.

The middle trunk is intimately related to the upper trunk in the common sheath. In the presence of scar tissue, the disentanglement of the nerve-trunks from the scalenes is often a most difficult and tedious affair.

At this stage in the supraclavicular dissection there are certain smaller branches whose recognition and conservation is important. The *phrenic* nerve lies on the anterior surface of the scalenus anticus and is easily seen when the sterno-mastoid is retracted mesially. The *long thoracic* nerve (nerve of Bell) should be found piercing the scalenus medius in the upper part of the wound, with the nerve to the rhomboids at a still higher level. Where there is little scar tissue the slender nerve to the *subclavius* is often demonstrable.

III. *The lowest trunk* which lies on the first rib next comes into the field, but is somewhat hidden until the suprascapular and transverse cervical veins have been divided and tied and the subclavian artery has been gently mobilized and retracted downwards. The parent roots of the trunk (8th cervical and 1st dorsal) may be fully exposed by detaching the whole or part of the scalenus anticus muscle from the rib. The thin fascial covering over the pleural dome and the pleura itself are easily torn, an accident of little significance, but one which should be avoided if possible.

Removal of a cervical rib.—As the exposure of the lowest trunk is the anatomical basis of the removal of a cervical rib, the special features of this operation are conveniently described here.

[illegible] attached below to the first dorsal rib. (2) In marked contrast is the fully developed cervical rib articulated to the vertebra and fused at its anterior end to the first rib.

The relation of the plexus trunks to the extra rib is also variable. A common arrangement is for the 7th cervical (or middle trunk) to cross its bony part, whilst the 8th cervical (or lowest trunk) passes over the [illegible] lies in front of the [illegible] may be unusually [illegible] vessels often run transversely in close contact with the rib. The subclavian vein, at a lower level, is out of the operation field. In the rudimentary type, the costal process lies hidden in the fibres of the middle scalene and is most readily approached between the upper and middle trunks; adequate retraction in this interval also allows the fibrous band to be clearly displayed. After the "rib" has been clearly defined and the neurovascular structures related to it freed, it is divided above at the level of the transverse process, and below at its junction with the first dorsal rib. When all muscular and fascial attachments have been divided, the "rib" can be neatly lifted out of the wound. If a periosteal sheath is left behind re-formation of the rib may occur.

Removal of the 1st dorsal rib.—Removal of a normal or rudimentary 1st dorsal rib has been practised with considerable success in certain cases of compression neuritis of the lower trunk where no definite cervical rib has been demonstrable. It is probable, however,

that the neuritis in these cases is due to the presence of the fibrous band contained in the scalenus medius, which represents the 7th cervical rib in its most rudimentary stage.

As removal of this band or division of the muscle alone is sufficient to free the lower trunk, it should rarely be necessary to resect the portion of rib to which both the band and the middle scalene are inserted. If for any reason removal of part of the rib is considered desirable, the plexus trunks should be freed and retracted as described. The middle scalene attachment is then separated from the upper surface of the rib, the intercostals and serratus from the outer border,



Fig. 215.—Complete exposure of brachial plexus after division of clavicle.

and lastly, the pleural fascia from its inner border. Carefully protecting the pleura, the bared portion of the rib is divided in front and behind, and removed.

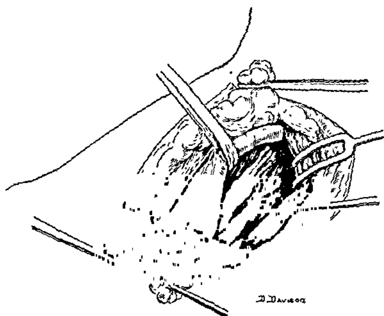
A considerable "dead space" is left, which should be obliterated by the deeper sutures.

Exposure of the complete plexus. (Fig. 215.)—This is required in the grave lesions involving multiple trunks when end-to-end suture is necessary. The supraclavicular exposure is the first stage; the infraclavicular exposure is effected in the following manner. The additional skin incision will be required.

1. **Division of the clavicle.**—The clavicle is bared subperiosteally in its middle third and drilled on each side of the proposed line of

section. The drill holes should be so placed that the suture knot will lie buried under the lower border of the bone when the ends are approximated. The section is conveniently begun by means of a Gigli saw and completed by bone-cutting forceps. The shoulder now drops backwards and downwards and a gap is opened up.

2. **Exposure of the infraclavicular nerve-trunks.** When the ends of the clavicle are retracted, the nerve-trunks are still hidden by the *subclavius muscle and costo-coracoid membrane.* This musculo-aponeurotic barrier must be cautiously divided and the dissection continued lower down in the interval between the deltoid and pectoralis major fibres. The external anterior thoracic nerve is often seen at



brachial plexus trunks.
nner trunks have been
tebral foramina.

this juncture, and, as the apex of the axilla is opened up, the three *secondary* trunks (cords) are identified in close relation to the axillary vessels, their sheaths being most intimately connected. The *outer* and *posterior* cords lie above and lateral to the vessels. The *inner* cord is just on the point of crossing behind the artery.

Repair of plexus lesions. Supraclavicular injuries.—(1) In the graver traction lesions both in the child (birth palsy) and adults, formidable difficulties are encountered in the actual exposure and identification of the nerve-trunks, and in their subsequent repair. In multiple trunk injuries the lesions are invariably concentrated at different levels, with the result that the supraclavicular nerves later become incorporated in a dense mass of scar which also contains the fibrous remains of the scalene muscles But in the midst of such an extensive cicatrix, nerve-bundles often remain intact and further recovery of function may be anticipated. The 5th and 6th nerves are

usually recognizable just below the cervical transverse processes, but almost immediately plunge into the block of scar. The 7th nerve joins a little lower down. A not uncommon condition is to find the middle trunk completely avulsed at the level of the intervertebral foramen (Fig. 216). The lower trunk is generally intact, although much indurated. Just above the clavicle the distal trunks are seen to emerge from the lower pole of the cicatricial mass. In this complex scar Erb's point and the various divisions and fusions of the primary trunks which form the secondary plexus trunks lie hidden. In my experience it is often possible by patient dissection to disentangle nerve-trunks which show naked-eye pseudo-continuity. The choice between a *neurolysis* and the radical operation of *resection and suture* must then be made. If there are very few intact bundles a neurolysis will in no way further the regenerative process. On the other hand, in a removal *en masse* of the intervening block of scar, conducting bundles are almost certain to be sacrificed and a considerable gap remains to be closed, with the distal nerve-stumps outnumbering the proximal stumps. Experience has shown that it is wise to adopt a conservative attitude towards multiple trunk lesions when, after resection, end-to-end suture may prove difficult or impracticable. When the main nerve-trunks have been isolated, the fibrous remains of the scalenus anticus should always be removed, care being taken to preserve the phrenic nerve. This step allows the nerve-trunks to be mobilized to the utmost, and in my opinion is essential in a neurolysis of the plexus.

In the rare lesions treated by resection, when suture is performed under considerable tension, the most complete relaxation of the brachial trunks is required, with the head and shoulder approximated and the upper arm in full elevation.

(2) *Circumscribed lesions* of the plexus are more easily dealt with. Of these the traction injury concentrated at Erb's point is perhaps the most familiar type. When resection is performed at this level, the operation consists of suture of *two* proximal trunks (5th and 6th) to *three* distal trunks (suprascapular nerve, branch to the outer cord, branch to the posterior cord). In spite of discrepancies in calibre, it is generally possible to effect an accurate and artistic repair.

Infraclavicular injuries, when due to wounds, may be complicated by involvement of the great vessels. In non-fatal cases the axillary artery has usually been ligatured as a life-saving measure, the nerve injury presenting itself for treatment at a later date. Where the arterial lesion is incomplete at the onset an aneurysm may develop. The nerve-trunks are generally found closely adherent to the aneurysmal sac, or to the remains of the artery. After freeing the nerves, the fibrous cord of the thrombosed vessel should be removed entirely.

Closure of the wound.—Where, after complete removal of the scar tissue surrounding the supraclavicular trunks, it has been impossible to conserve the supraclavicular fat-pad, little more than the skin-flap may remain to cover the repaired nerves. Under such circumstances

it is wise to introduce a connective tissue covering for the supraclavicular triangle. For this a sheet of fascia lata affixed by a few sutures at the edges is most satisfactory. Whenever possible the platysma should be restored by accurate suturing. The clavicle ends are best apposed and fixed by double silkworm-gut sutures with the knots well buried. The skin incision should be closed with a view to ensuring a creditable cosmetic result.

Post-operative position.—The position of fullest relaxation of the repaired trunks should be maintained for a week. At the end of this time the head may be released, but the arm should not be lowered until a fortnight has elapsed. Relaxation of the paralysed muscles will be continued until signs of recovery appear. A special effort should be made to prevent matting of the tissues in the supraclavicular region by the encouragement of active movements.

Exploration of the Plexus Cords and Chief Branches in the Axilla

Position of patient.—The upper limb is placed at right angles to the operating table, resting on a narrow support.

Skin incision.—Beginning below the clavicle, the incision runs downwards over the anterior axillary fold, and is continued in the upper arm along the line of the coraco-brachialis muscle.

Exposure of the nerve-trunks.—The pectoralis major fibres are divided freely, and the nerve trunks first approached in the lower part of the wound, and next at the apex of the axilla. With the proximal and distal exposure completed, it is simple to work downwards and display the trunks in their middle course. In the *distal* part of the field the inner edge of the coraco-brachialis is defined as the main guide to the median nerve, which overlaps the axillary artery on the lateral side. The *ulnar* nerve is mesial to the vessel, but in a more posterior plane. At the *proximal* limits of the wound, the pectoralis minor muscle is found to screen off a considerable area, and is therefore best divided. Immediately below the clavicle the three secondary plexus trunks are identified in relation to the vessels. At a lower level, the main upper limb nerves are displayed in turn: (*a*) On the outer wall of the axilla, at the level of the coracoid, the *musculo-cutaneous* nerve is seen to enter the *coraco-brachialis*. (*b*) The outer head of the *median* nerve leads to the main trunk, which runs lateral to the axillary artery. The proximal part of the median nerve is surrounded by the venæ comites of the axillary artery, and its separation must be carried out with caution. (*c*) The *ulnar* nerve is in close relation to the axillary vein. Near by are the less important sensory nerves—the internal cutaneous and lesser internal cutaneous—which are likely to escape recognition where dense scar is present. (*d*) The *musculo-spiral* nerve is hidden from view, as it lies on the posterior axillary wall. In the upper part of its axillary course it is approached

by retracting the larger vessels and nerve-trunks outwards. Lower down, the interval between artery and vein is the natural plane; the former is retracted with the median and musculo-spiral nerve, and the latter with the ulnar (Stiles). The upper branches supplying the *triceps* muscle appear at the level of the *latissimus dorsi* tendon, and should be carefully protected (*c*) The smaller branches of the posterior cord — the *circumflex* and *subscapular* nerves—can be exposed if necessary at this stage. In actual practice exploration of the plexus in the axilla is usually undertaken in the presence of extensive scarring and when the axillary artery is a mere fibrous cord. The disentanglement and identification of the nerve-trunks, often a formidable task, is rendered especially difficult by the venous hæmorrhage which so often occurs. Where suture of one or more of the large trunks is required, the arm must be brought close to the body, a position which renders closure of the wound awkward. In the majority of operations ample relaxation is afforded by bringing the upper arm vertical to the plane of the operating table. In this position the operator can work with little or no inconvenience.

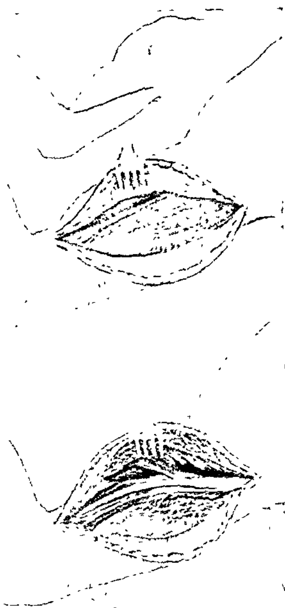


Fig. 217.—Exposure of the musculo-spiral nerve in the middle third of the arm.

Showing, at top, the skin incision; and the incision through the outer head of triceps and after division of the outer head of triceps.

Operations on the Musculo-spiral Nerve

Indications.—The lesions demanding operation may be: (1) *Penetrating wounds*, which are particularly common in modern warfare. Gunshot injuries are usually combined with comminuted fractures of the humerus, which show a predilection for non-union. Operative attack is almost invariably required on both the nerve injury and fracture, but the two procedures should *not* be carried out

at the same sitting. *In order to avoid the risk of a* recrudescence of infection and the disturbance of the repaired nerve, fixation of the fracture should be obtained *before the nerve-suture is attempted.*

(2) *Subcutaneous injuries* not infrequently complicate fractures of the shaft of the humerus or supracondylar fractures. Although spontaneous recovery is often seen, the nerve-trunk is occasionally severely damaged as it passes over a sharp projecting fragment, and in such circumstances operative repair becomes imperative.

Special anatomical features.—(1) The branches to the constituent heads of the triceps muscle, four in number, arise above the level of most injuries of this nerve. The uppermost branch (to the long head) is usually seen when the nerve is exposed in the lower part of the axilla as it crosses the latissimus dorsi. The lowest of the four (to the inner head) *arises just as the nerve-trunk enters the musculo-spiral groove.* All four branches are capable of being stripped from within the nerve-sheath high up into the axilla, where they *originate from a common* intraneural bundle.

(2) *The relation of the nerve-trunk to the triceps muscle is important.* As the nerve leaves the axilla it turns outwards in front of the long head of this muscle to enter the upper part of the musculo-spiral groove; in the groove it is covered by the outer head, and at first indicates the line of natural separation between the long and inner heads. In the lower third of the arm its intimate association with the triceps ceases and its course is now the line of cleavage between the brachialis anticus and the supinator longus muscle, where it passes through the external intermuscular septum.

(3) The superior profunda artery and veins cling closely to the sheath of the nerve over practically the whole extent of its course and, while *constituting a useful anatomical guide, often add to the* embarrassment of the operator when the deep scarring is well marked.

Position of the patient.—(1) For the conventional exposure in the lower two-thirds of the arm, the limb is drawn across the chest; (2) when the nerve is to be displayed just below the axilla, the arm must be abducted at right angles to the body.

Skin incision.—This runs obliquely across the postero-lateral aspect of the upper arm, beginning just above and behind the *deltoid* insertion, and ending in the *antecubital* fossa a little below the external epicondyle. (Fig. 217) For the intra-axillary exposure, a separate *incision on the mesial aspect of the* upper arm will be necessary. The combined incisions are required for gross lesions in which a formidable gap must be bridged.

(1) Infra-axillary exposure of the nerve.—The approach to the nerve behind the main vessels in the lower part of the axilla has already been described As the nerve runs over the latissimus dorsi towards the musculo-spiral groove, it is joined by the superior profunda vessels which render the dissection somewhat *difficult until* ligated. The

three upper motor branches and the first sensory branch also tend to complicate the exposure. The former should be delicately stripped up from within the nerve-sheath, and carefully retracted. A further obstacle is the inner head of the triceps, which is best circumvented by division of a few fibres of its origin. The nerve-trunk is now cleared from the lower third of the axilla to the upper limit of the musculo-spiral groove. Further distal exposure will necessitate bringing the arm to the side and across the chest.

(2) **Exposure below the musculo-spiral groove.**—The interval between the *brachialis anticus* and the *supinator longus* is defined and opened up at the level of the external epicondyle, and the nerve-trunk discovered lying rather deeply. Closely affixed to its sheath are the small radial recurrent vessels, which must be separated and tied off. The nerve is easily followed upwards to the lower end of the groove. A large sensory branch (lower external cutaneous) is seen ; lower down it demarcates the line of fusion between the adjacent borders of the supinator longus and triceps muscles. The main trunk passes out of sight beneath the supinator longus, and here the small branch to this muscle should be identified.

(3) **Exposure in the musculo-spiral groove.**—In the upper part of the groove the line of the nerve indicates the natural cleavage between the *long* and *inner* heads of the triceps. A fascial expansion forms a roof to the groove, which is covered still more superficially by the *outer head* of the triceps. Both these structures must be divided in order to gain access to the nerve-trunk as it lies on the bone with the superior profunda vessels running above and to the outer side but *clinging intimately to its sheath.* (Fig. 217.) The lower motor branches are seen entering the triceps heads in the upper part of the wound, and the origin of the lower external cutaneous branch should also be displayed.

Repair of the lesion. (1) *Difficulties.—Occasionally,* in spite of the fullest relaxation afforded by the exposure described, end-to-end apposition of the nerve-stumps is not obtainable. In such circumstances it is advisable to transpose the nerve-trunk to the front of the arm, and thus gain at least an additional inch. The operation of *anterior transposition* comprises the following steps. (*a*) Exposure of the nerve in the upper third of the arm (infra-axillary approach). (*b*) Exposure of the nerve in the lower half of the upper arm. (*c*) Division of the nerve through the proximal bulb in the upper wound and through the distal bulb in the lower wound. This leaves the injured segment *in situ* in the mass of scar occupying the musculo-spiral groove (Danforth and Stiles). (*d*) Oblique tunnelling of the brachialis anticus muscle from the upper to the lower wound fairly close to the bone. (*e*) Displacement of the proximal and distal nerve stumps to occupy the tunnel. (*f*) Trimming of the nerve-ends, followed by suture.

(2) **Nerve-bed.**—The repaired nerve should be shut off from contact with the humerus by a muscle-flap from the triceps. Where there has

been an extensive destruction of the muscle, a fascia lata sheet should be interposed.

Closure of the wound.—The divided outer head of the triceps should be sutured, and the deep fascia restored as accurately as possible.

Post-operative position of limb.—The elbow is slung in flexion with the upper arm close to the body. The hand is bandaged on to a "cock-up" splint in the physiological position of rest. Cautious movement of the limb may be allowed at the end of three weeks.

Operations on the Posterior Interosseous Nerve

Injuries of this nerve are uncommon. The chances of successful operative repair are small for, from its origin from the musculo-spiral, the nerve has a very short course and immediately breaks up into a leash of fine branches.

Exposure.—The lower end of the musculo-spiral nerve is first identified as it disappears beneath the supinator longus muscle. The latter must be fully retracted, after being freed along both its anterior and posterior borders. The interval between the radial extensors and extensor communis digitorum is next opened up, and the neck of the radius demonstrated, clothed by the supinator brevis. The nerve enters the substance of this muscle at its upper limit, runs down between two definite layers, and emerges below via a small tendinous arch At this level the proximal branches are given off. By dividing the superficial fibres of the supinator brevis the parent nerve-trunk is completely displayed.

Operations on the Median Nerve

Indications. (1) *Subcutaneous injuries.*—In *supracondylar* fractures the nerve is occasionally bruised or torn by the lower end of the forwardly displaced diaphysis.

(2) Lesions due to *penetrating wounds* are familiar both in civil and military surgical practice. In the forearm the nerve is commonly damaged by particles of glass, and adjoining tendons are apt to be divided. In gunshot wounds of the upper arm the brachial artery may also be injured ; if an aneurysm develops, the nerve-trunk almost invariably becomes adherent to the sac wall.

Special anatomical features.—In the upper third of the forearm a clear idea of the origin and distribution of the motor branches arising in the antecubital fossa is necessary. A fairly constant scheme is as follows :*

(1) *Uppermost branch to the pronator radii teres.*—This is the first branch of distribution and, as a general rule, leaves the parent trunk just below the level of the internal condyle, but not infrequently may appear some little distance above this point Followed upwards within the sheath of the nerve, the branch is found to be continuous with bundles situated in the *lateral* half of the cross-section of the trunk. Below, just before its entry into the muscle, the branch

* Linell, *Journ Anat*, Jan , April, 1921, lv, 79.

divides into two twigs which supply the condylar and coronoid heads of origin. The latter may occasionally receive its motor-nerve as a separate branch.

(2) *Middle branch.*—A stout bundle arises from the antero-mesial aspect of the nerve-trunk about 2 cm. down the forearm. From this leash individual branches are given off to supply the flexor muscles arising from the internal condyle. The individual heads of origin are innervated by separate twigs formed by further subdivision.

(3) *Anterior interosseous nerve.*—The origin of this stout branch is seen after division of the pronator radii teres.

(4) *Branch to the flexor sublimis digitorum.*—In nearly 50 per cent. of individuals the median gives off a fine branch in the lower part of the forearm to innervate that part of the flexor sublimis digitorum muscle which belongs to the index finger.

Exploration of the Median Nerve in the Upper Arm

Position of the patient.—The arm is supported on a rest at right angles to the long axis of the table.

Skin incision.—This lies along the course of the brachial artery' beginning just above the antecubital fossa and ending at the level of the anterior fold of the axilla.

Exposure of the nerve-trunk.—The deep fascia is divided just posterior to the basilic vein, which shows as a prominent landmark. In the upper third of the arm the coraco-brachialis muscle is demonstrated and its mesial border retracted. The median nerve is at once found overlapping the brachial artery. From this level it is easy to trace the nerve-trunk downwards until the lesion is reached. In the lower third of the arm the median basilic vein must be divided and tied, and a few fibres of the bicipital fascia incised. Here the nerve lies well away from the main artery. The upper branch to the pronator radii teres muscle is usually visible some little distance above the level of the internal epicondyle. The nerve-trunk is now followed upwards to the level of the lesion.

Repair of the lesion.—In the presence of considerable scarring, disentanglement of the nerve is a tedious procedure. When the brachial artery is occluded, the fibrous cord is always found closely adherent to the nerve-trunk. Where resection and end-to-end suture are necessary, a change in position must be made. In theory the upper arm should be brought close to the trunk with the elbow and wrist flexed. But this would place the wound in an impossible situation for the operator. Comfortable access to the wound and adequate relaxation are obtained when the upper arm is brought into flexion at the shoulder, i.e. at right angles to the plane of the operating table. A radical removal of scar tissue is necessary as a preliminary to replacing the repaired or freed nerve in an intramuscular bed fashioned from the biceps.

Closure of the wound.—Reconstruction of the deep fascia should be attempted.

Post-operative position of the limb.—A malleable metal splint is applied with the wrist in flexion, and the arm is supported by a sling, the elbow being fully flexed. Three weeks later, *gentle* stretching of the flexed joints is begun.

Exploration at the Elbow and in the Forearm

Position of the patient.—As above.

Skin incision.—The incision begins to the inner side of the biceps tendon, runs across the antecubital fossa, and follows the midline of the forearm as far as required.

Exposure of the nerve at the elbow.—The bicipital fascia is divided and the median basilic vein tied. The nerve-trunk should be found at the level of the internal epicondyle, and the uppermost motor branch identified. The antecubital fossa is opened up by retracting the lateral edge of the pronator radii teres, and the nerve-trunk followed until it disappears beneath the superficial head of this muscle. The *ulnar artery* comes into the field close to the nerve, which is related even more intimately to the venæ comites of this vessel At this stage the second motor branch, a stout twig which arises from the antero-mesial aspect of the parent trunk, is demonstrable. The anterior interosseous branch is hidden lower down by the pronator radii teres It is often advisable to divide the superficial pronator fibres freely in order to gain adequate room ; this can be done without imperilling its nerve supply. Where the scarring is extensive the whole pronator should be sacrificed without hesitation. Where the lesion accompanies a supracondylar fracture, the nerve-trunk, unless completely divided, often becomes adherent to the irregular margin of the lower end of the shaft.

Exposure of the nerve in the forearm.—The nerve is situated deeply in the upper half of the forearm, and at this level troublesome hæmorrhage may be encountered.

(1) **Upper third.**—It is always advisable to isolate the nerve-trunk in the antecubital fossa before attempting to define it in the angle between the lower border of the pronator radii teres and the flexor carpi radialis. The radial border of the latter is the correct guide, and here the nerve lies at a considerable depth, covered by the radial head of the flexor sublimis digitorum. This structure must be cautiously divided and the nerve gently freed from its bed. The fragile venæ comites of the *radial artery* are here in close relation, and are apt to tear.

(2) **Lower two-thirds.**—The relation of the nerve to the flexor carpi radialis has already been indicated. Lower down, the nerve-trunk passes behind this obliquely running structure, and appears to become

almost completely enveloped in a muscular tunnel provided by the flexor sublimis digitorum. (Fig. 218.) The special motor branch which supplies the index portion of the flexor sublimis may be seen at this stage. Nearer the wrist the nerve approaches the surface, and is easily displayed after incision of the deep fascia along the ulnar border of the flexor carpi radialis tendon. The palmaris longus tendon, when present, lies almost exactly over the nerve-trunk. At the wrist the nerve passes deeply under the anterior annular ligament. In an extensive lesion it is often necessary to divide the roof of the carpal tunnel and follow the nerve into the palm.

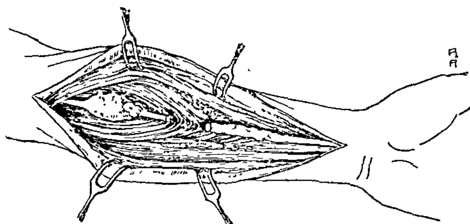


Fig. 218.—Exposure of median nerve in the lower two-thirds of forearm.
Illustrates the splitting of the belly of the flexor sublimis digitorum. The lesion depicted is of the complete anatomical type.

Repair of the lesion.—The position of relaxation which facilitates end-to-end suture is most awkward for the operator, but with the limb fully rotated out at the shoulder, the wound is not entirely hidden. Additional relaxation may be obtained by stripping up the proximal motor branches, and also by displacing the nerve in front of the pronator radii teres. In the upper third of the forearm a suitable intramuscular bed is readily fashioned. In the lower third the absence of muscular tissue and the proximity of the nerve to tendons render the surroundings more unsuitable. A convenient method of shutting off the nerve is to turn down a pedicled flap from the belly of the flexor sublimis digitorum.

Closure of the wound.—Accurate restoration of the deep fascia is often impracticable. In the upper third, the muscle bellies fall naturally together, and cover the repaired nerve. If there is an extensive loss of deep fascia in the lower third, a muscular flap or free fascial graft must be used to protect the nerve from the skin-flap.

Post-operative position of the limb.—This has already been described.

Operations on the Ulnar Nerve

Indications for operation.—(1) *Penetrating injuries* provide a considerable number of lesions demanding exploration. Gunshot injuries

may occur at any level, but in civil injuries the nerve is usually divided in the lower third of the forearm in company with adjoining tendons.

(2) *Subcutaneous injuries* are common in the region of the elbow where the nerve is unusually vulnerable. Lesions in the post-condylar groove are conveniently included under the heading *traumatic neuritis*, of which there are three main clinical types: (*a*) Lesions associated with *recent* fractures of the lower end of the humerus and dislocations of the elbow; (*b*) late ulnar palsy; and (*c*) recurring dislocation of the nerve.

Special anatomical features.—The proximal branches of distribution which arise in the region of the elbow joint are of great surgical importance, and may be described in the order of their origin.

(1) *The articular branch to the elbow joint.*—This usually arises above the level of the internal epicondyle, and after a very short course enters the capsule of the joint on its postero-mesial aspect.

(2) *Branches to the flexor carpi ulnaris.*—These present considerable variations, but commonly there are *two* main twigs which leave the main trunk just before it passes between the two heads of the muscle. The upper branch supplies the *olecranon head* and has a very short course; the lower branch enters the *condylar head* at a lower level. An additional supply to the condylar head is present in about 20 per cent. (Linell). This twig has a particularly long extra-muscular course.

(3) *Branch to the flexor profundus digitorum.*—This branch leaves the ulnar trunk after it has passed under cover of the flexor carpi ulnaris. It is much stouter than the branches arising above it, and it has an extramuscular course of at least 1 inch.

Exploration in the Upper Arm

Position of patient.—The arm is abducted and supported as in an exploration of the median nerve.

Skin incision.—The nerve lies immediately posterior to the line of the median nerve and brachial artery. The incision extends from the elbow to just below the anterior axillary fold.

Exposure of the nerve-trunk.—The basilic vein is the first guide, the fascial envelope being opened just behind it. In the upper part of the wound the median nerve usually appears, and is a useful landmark The ulnar nerve is now found lying on the triceps, and when traced downwards is seen to pass backwards away from the main artery and median nerve to reach the posterior compartment of the arm. In the region of the internal epicondyle the nerve is exposed after dividing the deep fascia just behind the internal intermuscular septum. The fine accompanying vessel (inferior profunda) should be carefully separated from the nerve-sheath and preserved.

Repair of the lesion.—The local conditions relating to scar and the nerve-bed in the upper arm have already been emphasized. The position of full relaxation differs from the one which is appropriate for the median nerve, in that the *elbow* must be maintained in *extension*. In

grave lesions the amount of relaxation afforded by this position is often insufficient, and it is necessary to transpose the nerve to the front of the elbow in order to take advantage of flexion of the joint. (Fig. 219.)

Exploration in the Region of the Elbow

This operation includes exposure in the lower third of the upper arm, in the post-condylar groove, and in the upper third of the forearm.

Position of the patient.—There are two alternatives: (*a*) The arm abducted and supported at right angles to the body; (*b*) the "reversed" position in which the limb is carried across the chest, the upper arm being held vertical to the operating table, with the elbow

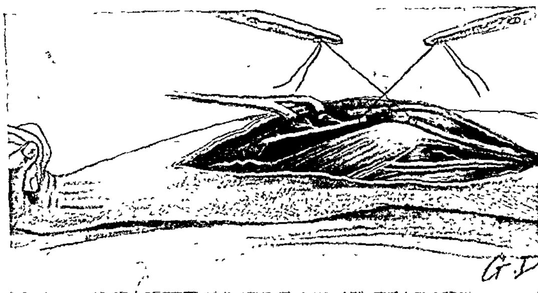


Fig. 219.—Exposure of ulnar nerve in upper arm and upper two-thirds of forearm.
Illustrates failure to secure end-to-end approximation with the elbow fully extended, the wrist flexed, and the arm adducted to the side. In such circumstances anterior transposition of the nerve is indicated.

and wrist fully flexed. This is simply the position of full relaxation of the nerve adopted at the beginning of the operation. The position presents considerable advantages, and has been employed by me as a routine for many years. (Fig. 220.)

Skin incision.—The incision begins in the lower third of the upper arm, and passes behind the internal condyle into the forearm, where the line of the nerve extends from a point midway between the epicondyle and olecranon to the radial side of the pisiform bone.

Exposure of the nerve-trunk.—The nerve is freed above the epicondyle and the fascia covering the post-condylar groove divided cautiously. The nerve-sheath is connected to the floor of the groove by filamentous strands. When continued into the forearm, the deep incision separates the fusion of the condylar and olecranon heads of

the *flexor carpi ulnaris.* After the muscular fibres are retracted the nerve is seen lying on the flexor profundus digitorum covered by a thin semi-transparent fascia. In this dissection the proximal branches must be identified in order and carefully preserved.

Repair of the lesion.—In all lesions of the nerve in the post-condylar groove the *repaired nerve should never be replaced in its original bed*, but should be transposed to the front of the elbow.

Exploration in the Forearm

The position of the limb and skin incision have been indicated. In an exposure limited to the lower third of the forearm the natural approach to the nerve is in the interval between the flexor carpi ulnaris and flexor sublimis digitorum. But in the upper third the two heads



Fig. 220.—Exposure of the ulnar nerve in the region of the elbow.
Note the "reversed" position of the limb and the skin incision.

of the flexor carpi ulnaris are separated. If this plane is followed in the middle and lower thirds of the forearm, the fibres of the condylar head must be detached from the tendon of insertion.

In the middle third of the forearm, the ulnar artery joins the nerve, and both structures lie in a common sheath. The venæ comites adhere closely to the epineurium and are easily torn during separation. The dorsal cutaneous branch of the nerve appears in the lower third.

Traced downwards to the wrist, the main trunk is found to pass close to the pisiform and to disappear into the palm under cover of the palmaris brevis.

Anterior Transposition of the Ulnar Nerve

This operation is well established, and is employed under the following conditions: (1) In extensive lesions (particularly gunshot injuries) at any level, as an aid to end-to-end suture; (2) for all lesions in the post-condylar groove (traumatic neuritis). The nerve-trunk is exposed and freed in the region of the elbow, as already described. Displacement forwards is prevented by the normal anchorage of the proximal branches. These are dealt with systematically. The

articular branch, being of trivial importance, is sacrificed. The motor branches are then stripped up in turn from within the sheath of the nerve-trunk, and also freed distally by dividing the muscle-sheaths at the points of entry. Considerable elongation results and the nerve-trunk falls easily in front of the epicondyle. The *new bed* is constructed by dividing the muscular fibres of the common flexor origin

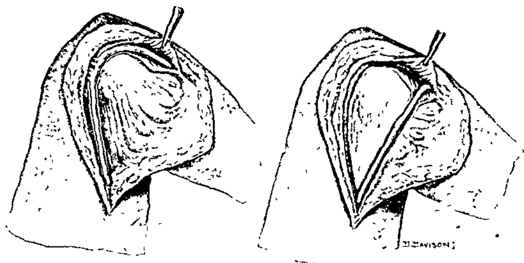


Fig. 221.—Anterior transposition of the ulnar nerve.
Left: Nerve-trunk exposed above the groove, in the groove, and in the upper third of the forearm.
Right: Nerve-trunk displaced in front of epicondyle—new bed provided by division of flexor muscle fibres

in front of the epicondyle. With the arm in the reversed position the incision forms the base of a triangle with its apex at the epicondyle (Fig. 221.) Where the lesion is treated by resection and suture the muscular mass can be tunnelled. The nerve-trunk is placed in its intramuscular bed with the elongated proximal branches now running backwards under moderate tension. As the nerve leaves the upper arm, it is seen to cross a somewhat tense bridge formed by the internal intermuscular septum, which must be eliminated by free division.

The suture line or the lesion (e.g. nerve spindle) lies well buried in the new bed after repair of the divided flexor aponeurosis and superficial muscular fibres.

Position of the limb after operation on the ulnar nerve.—The arm is bandaged to the side with the elbow flexed (if the nerve has been transposed) and the wrist flexed.

Exposure in the Hand

The deep branch of the ulnar nerve is conveniently approached by retracting the pisiform after its ligamentous attachments have been divided (A. K. Henry).

Digital Nerve Repair

In recent years digital nerve repair has assumed greater importance in the reparative surgery of the hand.

Operations on the Musculo-cutaneous and Circumflex Nerves

Isolated injuries of these nerves demanding operation are so exceedingly rare that a special description is unnecessary. The *musculo-cutaneous* nerve has a short intra-axillary course before piercing the substance of the coraco-brachialis muscle where its first motor branch is given off. Both this nerve and the *circumflex* may be repaired if necessary in conjunction with lesions of adjoining trunks.

Operations on the Great Sciatic Nerve

Indications. (1) *Penetrating injuries.*—Sciatic lesions are common in modern warfare and are often accompanied by symptoms of severe irritation with conspicuous trophic phenomena. (2) *Sciatica* (sciatic neuritis).—Direct stretching of the nerve-trunk is an obsolete procedure which need not be described.

Special anatomical features.—(1) The external and internal popliteal elements are separate nerve-trunks from the origin of the sciatic nerve within the pelvis, but are usually included in a common sheath. (2) As the sciatic emerges from the sacro-sciatic notch it consists of three definite parts, viz. the external popliteal bundle, the internal popliteal bundle, and a leash of branches to the hamstrings. The

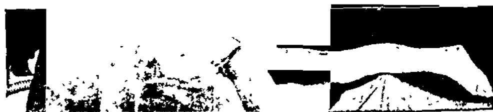


Fig. 222.—Position of patient for operations on sciatic nerve.
Note the extended position of the hip obtained by the adjustment of sandbags

latter can be freed and stripped from the common trunk for some distance inside the pelvis. (3) A special branch of supply to the biceps cruris (short head) arises from the lateral aspect of the main trunk about the middle of the thigh.

Position of patient.—The patient lies fully prone. In dealing with extensive gunshot lesions the position of full relaxation should always be instituted at the beginning of the operation. For this it is necessary to place the hip in *hyperextension* by careful adjustment of sandbags. (Fig. 222.) Further relaxation will be obtained during the operation by flexing the knee.

Skin incision.—In the buttock this should begin over the sacro-sciatic notch, and should sweep downwards and outwards to a point mesial to the trochanter. From this level the incision is carried vertically downwards as far as necessary in the midline of the thigh.

Exposure of the nerve-trunk. (1) **In the buttock.**—The gluteus maximus fibres are split above, and divided below towards the lower margin of the muscle. Brisk bleeding occurs from small twigs of the gluteal and sciatic vessels. No ill-results follow the splitting of this extensive muscle, but the alternative plan of detaching it partially from its insertion may be followed if preferred.

Retraction of the thick fibres brings into view the nerve-trunk lying in its capacious sheath on the quadratus femoris. Just below the notch the three distinct components—the external popliteal segment, the internal popliteal segment and the leash of branches to the hamstrings—should be identified. The latter can be stripped up to well within the pelvis if it is necessary to mobilize the main trunk to the utmost extent. The inferior gluteal nerve, which appears below the level of the pyriformis, should be recognized and its branches to the gluteus maximus conserved. Sometimes the two great divisions of the sciatic issue separately from the pelvis and are never conjoined.

(2) **In the thigh.**—Below the buttock the deep fascia is incised over the interval between the biceps and semitendinosus. Lower down the semimembranosus forms the mesial boundary. The small sciatic nerve is often a useful guide to this intermuscular interval. The biceps crosses the line of the nerve and it is often necessary to free the muscle extensively before retraction is possible. The nerve-trunk lies on the adductor magnus embedded in fat, and the two main divisions are easily distinguished within the common sheath. (Fig. 223.)



Fig. 223.—Anatomy of complete exposure of the sciatic nerve, showing relation of nerve-trunk to biceps cruris muscle

Repair of the lesion.—In extensive gunshot injuries the remains of the nerve-trunk are usually incorporated in a dense scar which includes the hamstring muscles. A considerable length of nerve-trunk may need resection and the lesion may approach the irreparable standard. When end-to-end suture is possible only under conditions of extreme tension, it is justifiable to use an absorbable stay suture.

In more localized lesions, one component of the sciatic trunk may be absolutely intact. In such circumstances "segmental suture" of either the peroneal or tibial division may be *indicated*. The uninjured component then becomes looped. The abundant muscular tissue of

the thigh and buttock makes the reconstruction of an adequate bed an easy matter.

Closure of the wound.—The gluteus maximus should be restored accurately and the retracted hamstring muscles brought together by suture of the deep fascia. With the limb in the position of relaxation, closure of the lower part of the skin incision is apt to be awkward.

Post-operative position of the limb.—The combination of hyper-extension of the hip and full flexion of the knee is best maintained in a plaster of Paris shell extending from the upper thorax to the middle of the lower leg. (Fig. 224.) This shell should be made some days beforehand with the limb in the required position. In it, the patient

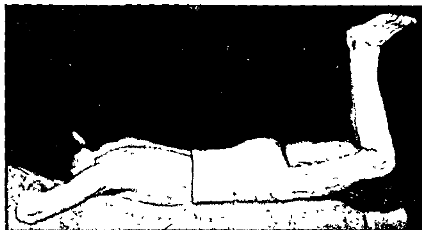


Fig. 224.—Position in which limb should be placed after suture of sciatic nerve. Shows the plaster cast which maintains hyperextension of the hip and flexion of the knee

is nursed on his face for the first 48 hours, and then turned on to the side. As an alternative, the lower limb may be thrust through a gap in a sectional mattress, with the patient on his back. Fixation methods improvised at the time of the operation mean added shock due to delay, and extreme discomfort in post-operative nursing. At the end of a fortnight the hip may be allowed to resume the ordinary position of slight flexion. Three weeks later gradual straightening of the flexed knee is begun.

Operations on the External Popliteal (Peroneal) Nerve

Indications for exploration.—(1) Penetrating lesions (2) Severe traction lesions necessitating operative repair occasionally accompany the uncommon adduction injuries of the knee joint.

Position of the patient.—The patient lies on his sound side, three-quarters prone, with the hip and knee flexed.

Skin incision.—This follows the line of the biceps tendon in the thigh, and ends behind the neck of the fibula. The incision may be prolonged over the upper part of the anterior compartment of the leg, if the terminal branches of the nerve are to be freed.

Exposure of the nerve-trunk.—After division of the deep fascia, the biceps is retracted and the nerve-trunk at once comes into view. Traced downwards, it is seen to disappear underneath the upper part of the peroneus longus muscle and to divide into the anterior tibial and musculo-cutaneous nerves. Just above the fibular neck, the large lateral cutaneous branch should be demonstrable.

Repair of the lesion.—When the lesion is close to the neck of the fibula, repair may involve separate suture of the anterior tibial and musculo-cutaneous nerves to the parent trunk. To obtain sufficient relaxation it may be necessary to expose the sciatic trunk for some distance in the thigh, and strip up the external popliteal component. A suitable nerve-bed is not always forthcoming but a flap from the peroneus longus or outer head of the gastrocnemius is the most useful shield. End-to-end suture is carried out with the knee flexed.

Position of the limb after operation.—This is identical with the one described for the sciatic nerve, except that extension of the hip is rarely necessary.

Operations on the Internal Popliteal (Tibial) Nerve

Indications for exploration.—Operations on this nerve are uncommon, and are almost entirely limited to penetrating injuries. Occasionally the nerve lesion may be associated with an aneurysm of the popliteal artery.

Position of the patient.—This is the same as for the sciatic nerve.

Skin incision.—A midline incision over the whole extent of the popliteal space is used.

Exposure of the nerve-trunk.—In the upper part of the popliteal space the nerve is found immediately after incision of the deep fascia. Lower down it lies over the thick-walled popliteal vein and passes out of sight where the two heads of the gastrocnemius converge. The stout motor branches supplying this muscle show up conspicuously. Where the perineural scar is abundant, or an aneurysm is present, disentanglement of the nerve from the vessels is difficult.

Operations on the Posterior Tibial Nerve

Indications.—This nerve is rarely explored. Exposure in the upper part of its course is the natural prolongation of the internal popliteal exploration. In the lower part of the leg the nerve comes nearer the surface.

Exploration in the Upper Two-thirds of the Leg

Skin incision.—This begins in the middle of the popliteal space and is continued downwards in the midline of the leg.

Exposure of the nerve-trunk.—The nerve is covered by (*a*) the muscle bellies of the gastrocnemii; (*b*) the soleus; and (*c*) the fascial roof of the deeper compartment of the leg. These various layers must be split vertically and retracted fully. The nerve is in close relation to

the thigh and buttock makes the reconstruction of an adequate bed an easy matter.

Closure of the wound.—The gluteus maximus should be restored accurately and the retracted hamstring muscles brought together by suture of the deep fascia. With the limb in the position of relaxation, closure of the lower part of the skin incision is apt to be awkward

Post-operative position of the limb.—The combination of hyper-extension of the hip and full flexion of the knee is best maintained in a *plaster of Paris shell* extending from the upper thorax to the middle of the lower leg. (Fig. 224.) This shell should be made some days beforehand with the limb in the required position. In it, the patient



Fig. 224.—Position in which limb should be placed after suture of sciatic nerve. Shows the plaster cast which maintains hyperextension of the hip and flexion of the knee

is nursed on his face for the first 48 hours, and then turned on to the side. As an alternative, the lower limb may be thrust through a gap in a sectional mattress, with the patient on his back. Fixation methods improvised at the time of the operation mean added shock due to delay, and extreme discomfort in post-operative nursing. At the end of a fortnight the hip may be allowed to resume the ordinary position of slight flexion. Three weeks later gradual straightening of the flexed knee is begun.

Operations on the External Popliteal (Peroneal) Nerve

Indications for exploration.—(1) Penetrating lesions (2) Severe traction lesions necessitating operative repair occasionally accompany the uncommon adduction injuries of the knee joint.

Position of the patient.—The patient lies on his sound side, three-quarters prone, with the hip and knee flexed.

Skin incision.—This follows the line of the biceps tendon in the thigh, and ends behind the neck of the fibula. The incision may be prolonged over the upper part of the anterior compartment of the leg, if the terminal branches of the nerve are to be freed

Exposure of the nerve-trunk.—After division of the deep fascia, the biceps is retracted and the nerve-trunk at once comes into view. Traced downwards, it is seen to disappear underneath the upper part of the peroneus longus muscle and to divide into the anterior tibial and musculo-cutaneous nerves. Just above the fibular neck, the large lateral cutaneous branch should be demonstrable.

Repair of the lesion.—When the lesion is close to the neck of the fibula, repair may involve separate suture of the anterior tibial and musculo-cutaneous nerves to the parent trunk. To obtain sufficient relaxation it may be necessary to expose the sciatic trunk for some distance in the thigh, and strip up the external popliteal component. A suitable nerve-bed is not always forthcoming but a flap from the peroneus longus or outer head of the gastrocnemius is the most useful shield. End-to-end suture is carried out with the knee flexed.

Position of the limb after operation.—This is identical with the one described for the sciatic nerve, except that extension of the hip is rarely necessary.

Operations on the Internal Popliteal (Tibial) Nerve

Indications for exploration.—Operations on this nerve are uncommon, and are almost entirely limited to penetrating injuries. Occasionally the nerve lesion may be associated with an aneurysm of the popliteal artery.

Position of the patient.—This is the same as for the sciatic nerve.

Skin incision.—A midline incision over the whole extent of the popliteal space is used

Exposure of the nerve-trunk.—In the upper part of the popliteal space the nerve is found immediately after incision of the deep fascia. Lower down it lies over the thick-walled popliteal vein and passes out of sight where the two heads of the gastrocnemius converge. The stout motor branches supplying this muscle show up conspicuously. Where the perineural scar is abundant, or an aneurysm is present, disentanglement of the nerve from the vessels is difficult.

Operations on the Posterior Tibial Nerve

Indications.—This nerve is rarely explored. Exposure in the upper part of its course is the natural prolongation of the internal popliteal exploration In the lower part of the leg the nerve comes nearer the surface.

Exploration in the Upper Two-thirds of the Leg

Skin incision.—This begins in the middle of the popliteal space and is continued downwards in the midline of the leg.

Exposure of the nerve-trunk.—The nerve is covered by (*a*) the muscle bellies of the gastrocnemii; (*b*) the soleus; and (*c*) the fascial roof of the deeper compartment of the leg. These various layers must be split vertically and retracted fully. The nerve is in close relation to

the posterior tibial artery, at first on its mesial side then crossing it to reach to its outer side. In the upper part of the wound the motor branches to the deeper muscles should be isolated and guarded.

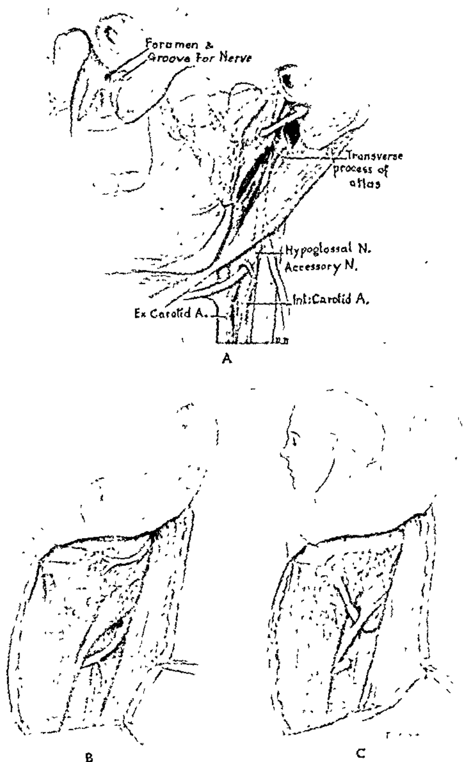


Fig. 225.—(A) Showing anatomical relationships of facial spinal accessory and hypoglossal nerves. (B) Exposure of facial and hypoglossal nerves. (C) Anastomosis of hypoglossal and facial nerves completed.

Exploration in the Lower Third of the Leg

The skin incision runs just behind the mesial border of the tibia. The edge of the soleus is defined and retracted after division of the deep fascia. The nerve and artery lie underneath a fascial roof in the interval between the flexor longus digitorum and the flexor longus hallucis. In the lower part of the field the tendon of the tibialis posticus comes into view.

Anterior Crural, Anterior Tibial, Musculo-cutaneous, and Plantar Nerves

For obvious reasons, lesions of the *anterior crural* nerve-trunk in the thigh at the level of its division into its multiple branches belong to the irreparable class. Exploratory operations on the anterior tibial, musculo-cutaneous and plantar nerves have little special interest or practical importance.

Operations for Cranial Nerve Injuries

In injuries of the cranial nerves, with the exception of the 7th and 11th, the problem of direct operative repair does not arise. The *spinal accessory* (11*th*) is easily exposed, but as in the majority of lesions there is considerable loss of nerve substance, the resulting gap can rarely be closed. Reference has already been made to the treatment of lesions of the *facial* (7*th*) nerve by various types of nerve anastomosis, operations which, though possibly only of academic interest, may now be described.

Facio-hypoglossal Anastomosis

Skin incision.—A fairly generous incision extending from the tip of the mastoid to below the great cornu of the hyoid bone is required.

Exposure of the facial nerve.—The deep fascia is divided, and the sterno-mastoid and posterior belly of the digastric are defined. The styloid process is the most important landmark, and is exposed by dissecting deeply underneath the lower pole of the parotid gland. The facial nerve is now sought as it emerges from the [illegible] If intact, it is divided by a te[illegible] severed within the facial ca[illegible] the foramen.

Exposure of the hypoglossal nerve.—The two main guides are the transverse process of the atlas and the occipital artery, around which the nerve hooks. The nerve is freed and approximated to the facial.

Anastomosis.—The hypoglossal nerve may be divided completely, or through two-thirds of its cross-section. The former is preferable in spite of the resulting sacrifice of one half of the lingual musculature. The proximal end is then sutured to the distal stump of the facial, the finest material being employed.

Closure of the wound.—As the operation is almost invariably conducted in an area free from scar, a suitable bed is readily provided.

Facio-glosso-pharyngeal Anastomosis

The skin incision described above is used, and the facial nerve exposed and its distal end prepared in the usual way. The glosso-pharyngeal nerve is found beneath the upper and posterior part of the

hyoglossus muscle, and is divided completely just proximal to its lingual branches. End-to-end suture between the two nerves is carried out.

Exposure of the glosso-pharyngeal nerve.—The glosso-pharyngeal nerve is divided close to the posterior border of the hyoglossus muscle, beyond the origin of the branch to the pharyngeal plexus. Difficulty may be experienced in isolating the nerve, and much time can be saved by defining the external and internal carotid vessels and exposing the nerve between them, whence it can be followed distally to make the division.

The posterior belly of the digastric has been exposed already in the isolation of the facial trunk, and the vessels should first be defined below this muscle and the latter then retracted upwards. The styloid process, with its attached muscles, can now be demonstrated. The trunk of the 9th nerve is found just under cover of the lower border of the stylopharyngeus and followed carefully forwards between the carotids to the posterior border of the hyoglossus.

In a thick-necked patient the dissection may be very difficult and tedious if the anatomical landmarks are not carefully defined at the outset.

A similar exposure can be used to evulse the nerve in glossopharyngeal neuralgia, but the dissection must be carried up nearer the base of the skull and the nerve pulled out from the jugular foramen.*

Nerve-grafting in Facial Palsy

Nerve-grafting has become the method of choice in destructive lesions of the facial nerve in the Fallopian aqueduct. The technique generally used is based on the pioneer experimental and clinical work of Ballance and Duel. The steps of the operation are as follows:—

(1) **Exposure of the nerve.**—The nerve is identified at the stylomastoid foramen and followed upwards. To expose the trunk proximal to the injury a radical mastoid operation is necessary. The nerve ends are freed and all intervening scar and granulation tissue is removed.

(2) ***Insertion of the graft.***—*A graft of sufficient length, equal in* calibre to the facial nerve, is taken from the middle cutaneous nerve of the thigh and is implanted in the gap. A single sheath suture at each end is sufficient, but if the graft lies snugly the sutures may be dispensed with.

VI. POST-OPERATIVE TREATMENT

Early stages.—Until the wound is healed the limb is usually retained in the position adopted at the end of the operation. This, however, should not be a period of total inactivity. In the *upper limb*, movements of the fingers are encouraged after a few days, and if necessary light massage may be applied to available surfaces. After removal of the sutures a greater surface area is exposed for physical treatment. Stretching of the flexed joint is begun, on the average, at the end of three to four weeks. In the *lower limb*, after suture of the sciatic nerve, stretching must be gentle and gradual, forced movements are

* See *Lancet*, August 22, 1931, ii, 397

absolutely prohibited. All the evil effects of a primary traction injury, i.e. rupture of axons, intra-neural fibrosis, may be set up in the proximal part of the nerve-trunk by too early and energetic stretching. A flexed joint stretches naturally when active movements are resumed. Where a contracture proves to be resistant a " turn buckle " plaster is often effective.

Later stages.—The patient should be given the benefit of a full physiotherapeutic régime. It must be realized, however, that such treatment has no direct influence on the regeneration of nerve-fibres, but simply helps to improve and conserve the nutrition of the tissues controlled by the injured nerve. Physical treatment may be classified under two headings :—

(1) Postural treatment.—The paralysed muscles must be retained in the position of *moderate relaxation* by some form of light and comfortable splinting. The correct posture also prevents the development of contractures. The appropriate positions for the various nerves are given in the following table :—

Nerve	Physiological Position of Muscle Relaxation	Mode of Retention or Splinting
Brachial plexus	Abduction at shoulder ; flexion at elbow. Hand in position of physiological rest.	Shoulder abduction splint or axillary muff.
Musculo-spiral nerve	Hand in position of physiological rest, viz. : wrist dorsiflexed ; fingers very slightly flexed at metacarpal and interphalangeal joints ; thumb abducted and extended ; " cricket-ball " or " bottle-grasping " position.	Long " cock-up " splint for nightwear. Short " cock-up " splint or cock-up glove with extension elastics for day wear.
Median nerve	Hand in position of physiological rest.	Opposition splint for thumb.
Ulnar nerve	Hand in position of physiological rest.	Splinting for correction of an already developed claw contracture. It is often sufficient to apply a corrective splint at night only.
Sciatic nerve	Foot dorsiflexed at right angles to leg.	For night wear a simple rectangular metal splint. Walking appliance : single or double short steels with some form of uplifting spring or foot-drop stop.

hyoglossus muscle, and is divided completely just proximal to its lingual branches. End-to-end suture between the two nerves is carried out

Exposure of the glosso-pharyngeal nerve.—The glosso-pharyngeal nerve is divided close to the posterior border of the hyoglossus muscle, beyond the origin of the branch to the pharyngeal plexus. Difficulty may be experienced in isolating the nerve, and much time can be saved by defining the external and internal carotid vessels and exposing the nerve between them, whence it can be followed distally to make the division.

The posterior belly of the digastric has been exposed already in the isolation of the facial trunk, and the vessels should first be defined below this muscle and the latter then retracted upwards. The styloid process, with its attached muscles, can now be demonstrated. The trunk of the 9th nerve is found just under cover of the lower border of the stylo-pharyngeus and followed carefully forwards between the carotids to the posterior border of the hyoglossus.

In a thick-necked patient the dissection may be very difficult and tedious if the anatomical landmarks are not carefully defined at the outset.

A similar exposure can be used to evulse the nerve in glosso-pharyngeal neuralgia, but the dissection must be carried up nearer the base of the skull and the nerve pulled out from the jugular foramen.*

Nerve-grafting in Facial Palsy

Nerve-grafting has become the method of choice in destructive lesions of the facial nerve in the Fallopian aqueduct. The technique generally used is based on the pioneer experimental and clinical work of Ballance and Duel. The steps of the operation are as follows:—

(1) **Exposure of the nerve.**—The nerve is identified at the stylo-mastoid foramen and followed upwards. To expose the trunk proximal to the injury a radical mastoid operation is necessary. The nerve ends are freed and all intervening scar and granulation tissue is removed.

(2) **Insertion of the graft.**—A graft of sufficient length, equal in calibre to the facial nerve, is taken from the middle cutaneous nerve of the thigh and is implanted in the gap. A single sheath suture at each end is sufficient, but if the graft lies snugly the sutures may be dispensed with.

VI. POST-OPERATIVE TREATMENT

Early stages.—Until the wound is healed the limb is usually retained in the position adopted at the end of the operation. This, however, should not be a period of total inactivity. In the *upper limb*, movements of the fingers are encouraged after a few days, and if necessary light massage may be applied to available surfaces. After removal of the sutures a greater surface area is exposed for physical treatment. Stretching of the flexed joint is begun, on the average, at the end of three to four weeks. In the *lower limb*, after suture of the sciatic nerve, stretching must be gentle and gradual; forced movements are

* See *Lancet*, August 22, 1931, ii, 397

absolutely prohibited. All the evil effects of a primary traction [illegible], i.e. rupture of axons, intra-neural fibrosis, may be set up in the proximal part of the nerve-trunk by too early and energetic [illegible]. A flexed joint stretches naturally when active movements are [illegible]. Where a contracture proves to be resistant a "turn buckle" [illegible] often effective.

Later stages.—The patient should be given the benefit of a [illegible] physiotherapeutic régime. It must be realized, however, that [illegible] treatment has no direct influence on the regeneration of [illegible] but simply helps to improve and conserve the nutrition of the [illegible] controlled by the injured nerve. Physical treatment may be [illegible] under two headings :—

(1) **Postural treatment.**—The paralysed muscles must be [illegible] the position of *moderate relaxation* by some form of light [illegible] able splinting. The correct posture also prevents the [illegible] contractures. The appropriate positions for the [illegible] given in the following table :—

Nerve	Physiological Position of Muscle Relaxation	[illegible]
Brachial plexus	Abduction at shoulder; [illegible] at elbow. Hand in position of [illegible] rest.	[illegible]
Musculo-spiral nerve	Hand in position of [illegible] rest, viz.: wrist [illegible] fingers very [illegible] metacarpal and [illegible] geal joints; [illegible] and [illegible]	[illegible]

Modern practice has proved the value of lightweight splints with spring attachments which return the hand to the position of rest after active movements.

(2) Nutritional treatment.—The following measures should be prescribed as a routine :—

(*a*) *Heat.*—The paralysed limb should be kept warm Woollen gloves, sleeves, or extra socks are essential in cold weather. The limb should be adequately warmed before the application of massage or electrical treatment. The methods of obtaining hyperæmia in common use are (i) dry heat—radiant-heat baths; paraffin-wax baths; diathermy; (ii) moist heat—simple hot-water baths or whirlpool baths. In irritative lesions, however, heat is contra-indicated, pain and hyperæsthesia being relieved only by intense cold, e.g. evaporating lotions and the like.

(*b*) *Massage.*—In the earlier stages this should be superficial and carried out with gentleness. As recovery sets in, the depth and vigour should be increased.

(*c*) *Electrical stimulation.*—The denervated muscles should be made to contract at each sitting, care being taken to avoid fatigue. At first the galvanic current only will be used; in the recovery stage faradic excitation is substituted as soon as an adequate response is noted. The stimulation must be accurately applied to the affected muscles, and leakage of current through to the antagonists avoided.

(*d*) *Muscle re-education.*—True re-education is practised when definite voluntary power has appeared, and for some time is best combined with regular faradic stimulation. The recovering muscles are re-educated from what is known as the zero position, where the effect of gravity is eliminated and the load is nil. As voluntary power increases, the load and range of movement are increased *pari passu*. Re-education may also be used in training a patient to develop "trick" or "substitute" movements before the onset of true recovery. Where imperfect regeneration of the injured nerve is anticipated such trick movements have considerable economic value

(*e*) *Exercises and curative work.*—In the final stages of recovery the development of co-ordinated and purposive movements is the most important therapeutic problem. This end is best attained by carefully prescribed exercises. Where patients are treated in larger numbers, handicraft training in curative workshops is a most valuable adjunct.

VII. RESULTS OF OPERATIONS FOR THE REPAIR OF NERVE INJURIES

In judging the true end-results of operations for the repair of peripheral-nerve injuries, it is necessary to make a clear distinction between two standards of assessment, the physiological (or neurological) and the functional (or economic). The former represents the amount of conductivity which has been restored to the nerve as measured by the usual clinical and electrical tests. The latter denotes the capacity

which the limb has regained, apparently as the result of the operation. The two standards do not necessarily run parallel. A good functional result may accompany a poor neurological result ; on the other hand, with a satisfactory or almost perfect neurological result there may be little improvement in function. The reasons for such discrepancies are not far to seek. A complete lesion of a peripheral nerve may cause little practical disablement in certain individuals. Thus the elimination of the function of the ulnar intrinsic muscles of the hand is of importance only to those whose occupation demands the finer hand movements. This may be contrasted with the more serious disablement which is always seen in a complete lesion of the median nerve, where the anæsthesia of the index finger alone impairs the capacity of the hand for most types of work. Again, the successful repair of the nerve, even if restoration of conduction and function go hand in hand, may be of no practical value to the patient if other structures are seriously damaged. Finally, delay in recovery may be due to psychical causes. It is now recognized that nerve recovery requires a much longer time than used to be thought, and in almost every case the period will be one of years rather than months. The age of the individual is also an important factor, recovery being much quicker and more complete in young individuals, in whom normal growth is still active.

Results of End-to-End Suture

Primary suture.—Perfect recovery of both motor and sensory functions may follow the early repair of a clean-cut division of a nerve where aseptic wound healing has occurred. Such results, however, are exceptional and are more likely to be seen after delayed primary sutures than in immediate primary sutures.

Secondary suture.—The results in late sutures on the whole tend to be disappointing. Of the factors which influence the standards of recovery the following are the most important:—

(*a*) *Topographical confusion.*—A certain amount of "shunting" of regenerating nerve-fibres along alien channels in the distal trunk occurs after most nerve-sutures. Thus, motor fibres grow down sensory sheaths ; sensory down motor sheaths ; pain fibres reach "heat" endings, and so on. In lesions in which extensive resection is necessary, a considerable disturbance of the intraneural pattern results. Such [illegible] imperfections

(*b*) *Changes in the nerve-trunk.*—The rôle of cicatricial shrinkage is well demonstrated in the changes which occur at various levels. Above the suture, an interstitial neuritis may extend for many inches. At the site of suture, shrinkage may result in the obliteration of nerve-fibres which have re-established communication with their end organs. Below the suture, the axis cylinders often remain imperfectly myelinated, and the shrinkage in the diameter of the peripheral stump limits the re-entry of new axons. The sum of such changes means scanty re-innervation

Sensory recovery	Protopathic plus epicritic (partial) 9
	Protopathic alone (complete 3, incomplete 3) 6
	Complete sensory recovery .. 1
	No sensory recovery 3

Median nerve—43 cases (upper arm 22, forearm 21).

Proximal muscles: Pronator radii teres, wrist flexors and long finger flexors.
Distal muscles: Median intrinsics of the hand.

A. Upper arm.

Motor recovery	Proximal muscles plus distal muscles (partial) 7
	Proximal muscles alone .. 15
Sensory recovery	Protopathic alone 11
	Protopathic plus epicritic (partial) 6
	No sensory recovery 5

B. Forearm.

Motor recovery	Thenar muscles 9
	No motor recovery 12
Sensory recovery	Protopathic alone 9
	Protopathic plus epicritic (partial) 10
	No sensory recovery 2

Sciatic nerve—27 cases.

Motor recovery	Internal popliteal plus external popliteal muscles 20
	Internal popliteal alone .. 7
Sensory recovery	Protopathic alone (complete) .. 2
	Protopathic alone (incomplete) 14
	Protopathic plus epicritic (partial) 6
	No sensory recovery 5

External popliteal nerve—12 cases.

Motor recovery	All muscles 6
	One or more muscles 6
Sensory recovery	Complete 4
	Protopathic alone 6
	No sensory recovery 2

Results of Nerve Suture (Gunshot Wounds)

German Clinics—(Tabulated by Foerster) (1929)

	Number of Cases	Successful	Cured	Improved	Failure
		per cent	per cent.	per cent	per cent.
Foerster .	370	96	55	42	3
Stracker .	147	75	13	62	25
Stoffel .	127	62	23	36	38
Spielmeyer .	100	59	23	36	41

Medical Research Council Special Report. No. 282, 1954

Peripheral Nerve Injuries

I. RESULTS OF NERVE SUTURE

1,441 injuries. Maximum follow-up 3 years (1,108 cases)

NERVE	MOTOR	SENSORY
Ulnar—low suture	78 5% useful recovery 16% independent movements of fingers	46% useful recovery 30% higher grade
Median—high suture low suture	90% useful recovery in long flexors	53% useful recovery 68% useful recovery
Radial	36% good recovery 61% use of extensors of thumb and index and proximal muscles (i e., as good as flexor transplant) 89% recovery of proximal muscles (i.e , not as good as flexor transplant)	
Medial popliteal	56% useful recovery (strong action of calf against gravity and resistance)	17% recovery of tactile sensation 80 5% recovery to pin prick
Lateral popliteal— high suture low suture	36% able to dorsiflex foot against gravity 13% able to dorsiflex foot against gravity and resistance 59% able to dorsiflex foot against gravity 32% able to dorsiflex foot against gravity and resistance	

II. BRACHIAL PLEXUS—SPONTANEOUS RECOVERY

Group I. 117 cases—Roots of trunk of C 5 C.6 —good
II 12 cases—Lesions of post cord—fair
III 88 cases—Lesions of medial cord—C 8 T 1.—poor.

III. NERVE GRAFTING

42% as good as suture at same level
68% useful recovery

SUMMARY OF RESULTS

	RECOVERY	RECOVERING	PARTIAL RECOVERY	FAILURE	TOTAL
A. Digital	7	—	3	6	16
B Cable.					
Median	4	—	2	1	7
Brachial plexus	—	1	1	3	5
Others	3	—	2	—	5
C Main trunk					
Median	9	2	2	2	15
Sciatic	—	1	3	5	9
Others	1	—	—	3	4
D. Inlay for partial division	4	1	—	1	6
	28	5	13	21	[illegible]

CHAPTER X

OPERATIONS ON BLOOD-VESSELS

By G. GREY TURNER and LAMBERT ROGERS

with a section on Blood Transfusion by Peter Martin

Surgical anatomy.—The walls of arteries are composed of three coats. The external or tunica adventitia consists of a network of elastic fibres and connective tissue. In this coat the blood-vessels and the network of sympathetic fibres supplying the artery are found. It is only loosely attached to the middle coat, or tunica media, which is the main framework of the vessels, being composed of strong elastic fibres with a lesser proportion of plain muscle, both closely bound together with connective tissue. The inner coat or intima is formed by a layer of elastic tissue supporting the smooth elongated endothelial cells which line the vessel. It is this delicate lining which prevents clotting and wherever it is interrupted or roughened from injury or disease thrombosis occurs.

All vessels lie in a bed of loose cellular tissue, which acts like a bursa around them and permits their free movement. The arteries are not only in a state of tension or tonus as regards their lumina but as regards their length, for they retract to a considerable extent when cut across. This retraction is associated with contraction of the lumina at the cut ends and is an important factor in the natural arrest of hæmorrhage. The elastic tissue acts in the opposite way when a lateral gap occurs for its contraction then tends to pull this open.

The arteries of the limbs receive a supply of vaso-constrictor nerves through sympathetic fibres which reach them by continuity with the plexuses on the great vessels of the trunk and at various levels throughout the limb by fibres which travel to the vessels *via* the peripheral nerve-trunks. The whole mechanism is regulated from the vaso-motor centre in the medulla which in turn is subject to influences from the higher cerebral centres.

The veins are constructed on the same general plan as the arteries except that the three coats are much thinner. The inner coat is less easily ruptured and the middle coat contains a smaller proportion of muscular tissue. A characteristic feature is the presence of a system of valves which prevent reflux of blood. Each valve consists of two semilunar flaps attached to opposite sides of the vessel wall, each with a small sinus on its cardiac side. The distension of these sinuses closes the valve and prevents regurgitation When the veins are chronically distended the valves are rendered incompetent. Valves are absent from the superior and inferior venæ cavæ and from the pulmonary veins, as well as from the portal vein and its tributaries. They are very scanty in the veins of the lower part of the rectum and

in the iliac and common femoral veins. The circulation through the veins is greatly assisted by the pressure of the surrounding muscles.

Changes in disease.—In arterio-sclerosis the arteries become hard, tortuous, elongated and loco-motor. Calcification which is sometimes evidenced in X-ray films makes the vessels friable so that they easily break across unless very gently manipulated. The increase in length of the vessels is sometimes important since because of it an abdominal aneurysm tends to be lifted away from the vertebral column. The syphilitic aneurysm on the other hand erodes the vertebræ because the artery does not lengthen as it does in arterio-sclerosis.

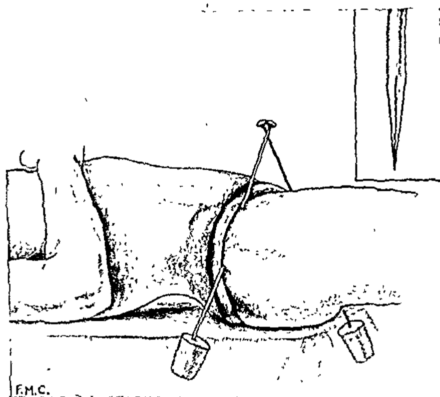


Fig. 226.—Wyeth pins retaining rubber tourniquet in position high up on the thigh. Inset shows the point of the pin.

Physiological considerations.—When the peripheral circulation of a limb is in jeopardy, whether through disease or injury of the main vessels, the limb should be kept cool to diminish its metabolism and the demands therefore made on its blood supply. It should be elevated to heart level and the body should be heated to relax the peripheral vessels. The old teaching of keeping the limb warm was contrary to sound physiology and practice.

The control of the circulation through a limb is necessary in many operations on the vessels of the extremities. The method most generally satisfactory, and to be employed whenever possible, is the

rubber tourniquet. Much has been said about the harmful effects of the tourniquet; these are mostly the result of long application, but, even when used for a short time during an operation, damage may be caused to the nerve-trunks of a thin upper limb. The best tourniquet for the arm is of the pneumatic type.* The inflatable cuff of a sphygmomanometer answers well unless the limb is very bulky. Of all

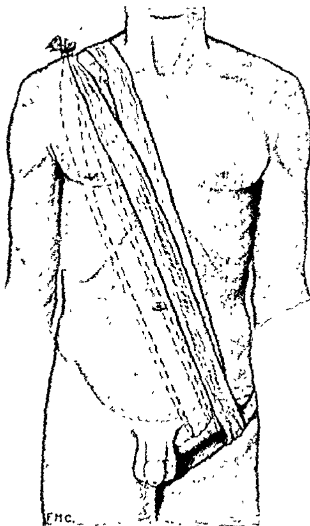


Fig. 227.—Rubber tourniquet high on thigh, retained in position with shoulder sling.

the varieties of tourniquet the Esmarch rubber bandage, 2½ in. wide, is the most generally useful.

Whenever conditions will allow, the limb should first be partially exsanguinated by elevation. For this purpose it is held high above the body for three minutes As a result, not only is the venous return assisted, but, as shown experimentally by Lister in 1879, there is also an active contraction in the arteries limiting the blood flow into the limb. While the limb is still elevated the tourniquet is applied well

* Grey Turner, B M J, September 22, 1917

above the area to be operated upon and the part is then slowly restored to body level. If the lesion is near the trunk it may be very difficult to apply the tourniquet or to keep it in position during the necessary manipulations. In these circumstances Wyeth's pins (Fig. 226) or the sling method shown in Fig. 227, have been used, or as a temporary measure the main vessel can be controlled by the pressure of an assistant's fingers When these methods cannot be used, temporary or provisional occlusion of the main vessel by ligation or by a clamp such as Lynn Thomas's may be employed. It must be recognized that occlusion of the main vessel does not everywhere shut off the collateral circulation but, none the less, in certain situations it provides a most effective control. The artery chosen must be most gently handled, especially if it is likely to be degenerated. If a ligature is used the material must be thick and so lightly tied that there is no risk of injuring the intima. No. 3 catgut tied over a pad of gauze or a piece of rubber tubing slightly larger than the artery to be occluded, the tie of the ligature being placed over the gauze or tube, is very satisfactory. Alternatively the ligature may be of narrow (quarter-inch) tape or soft rubber tubing passed round the vessel with an aneurysm needle, the rather thick material being anchored to the eye of the needle with a fine catgut stitch. Such a ligature need not be tied but crossed with sufficient tension in front of the vessel and fixed with artery forceps. With a soft rubber tube as a ligature, gentle traction away from the body often suffices to control the circulation in vessels of moderate size (Fig. 228).

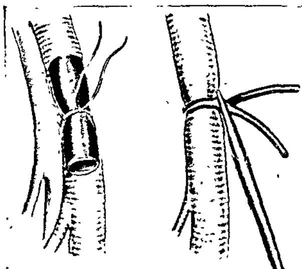


Fig. 228.—Left, temporary ligature tied over rubber tubing. Right, temporary ligature of soft rubber tubing held with artery forceps.

Temporary ligation in special situations.—For large vessels occlusion clamps are not very satisfactory and are very apt to slip out of position. In the neck temporary ligation may be required when operating for aneurysm or for the purposes of a " trial arrest " of circulation. The common carotid will usually be selected. The internal jugular vein should be carefully separated before attempting to pass the ligature. This should be carried out under the guidance of the eye otherwise it is so easy to perforate or tear the vein with the instrument—usually an aneurysm needle—used to carry the ligature. For very vascular conditions in the upper limb the ligature should be placed on the third part of the subclavian artery. In the lower limb occlusion

of the common femoral does little to control hæmorrhage through the collateral circulation, especially when this has become enhanced. In the latter case it is far better to place a second ligature just beyond the origin of the profunda femoris or temporarily occlude the common iliac which should be exposed by the abdominal route. This is also the best course when dealing with vascular conditions about the buttock.

Ligation of the main vessel of a limb.—Quite apart from the risk of gangrene, other considerations have stimulated surgeons to devise methods by which the main blood supply can be preserved. Rutherford Morison, Hogarth Pringle and others have pointed out and recent experience has confirmed the fact that a limb is rarely as efficient after the ligation of the main artery, many patients complaining of some degree of permanent weakness in the limb. The question is probably related to the degree of collateral circulation which has developed at the time the ligature is applied. The lesson seems to be to allow the passage of time for a collateral circulation to become established and when possible also to repair or replace the damaged vessel. "I must confess that in dealing with aneurysms I have usually found it necessary to carry out excision with ligature of both ends of the vessel and the results have been most satisfactory as regards absence of gangrene and subsequent function (G.G.T.)."

Methods of preventing intravascular clotting.—For this purpose the use of heparin is the most valuable of our resources. Until its introduction surgeons had to rely on (1) gentleness to avoid injury to the intima; (2) liquid paraffin to protect needles and suture material, and (3) irrigation with anti-coagulant citrate solutions. Nevertheless, much successful vascular surgery was carried out, especially experimentally, but the risk of thrombosis was great and its onset often marred otherwise good results. *Heparin* is an anti-coagulant prepared from animal tissues and also synthetically. It is used in solution either locally to alter the clotting time in an area, or generally by intravenous injection to increase the clotting time throughout the body. There is, however, a considerable risk of spontaneous post-operative bleeding, and watch should be kept on the prothrombin and clotting times when heparin or its ally dicoumarol (prepared from sweet clover) are being used.* For local use from 20 to 100 mgm of heparin in 20 ml. of saline solution is injected into vessels at the site of suture. Thereafter clotting time of the circulating blood can be delayed sufficiently to prevent thrombosis by the intravenous infusion of saline solution containing 10 mgm. of heparin to each 100 ml. This solution is run in at the rate of about 30 drops a minute. The infusion is continued for three to five days, depending on the estimated risk of thrombosis. Heparin may also be administered intermittently by intramuscular injection, 5,000 units at 6-hourly intervals for at least 48 hours being employed.

* Other preparations in use for the same purpose are "Tromexan" and "Dindevan".

It must never be forgotten that the most important criterion for success in vascular surgery is freedom from infection. Holman (1937) summarizes the essential requisites as: (1) absolute asepsis; (2) absolute hæmostasis, and (3) the anatomical dissection of tissues.

INJURIES OF ARTERIES

Arterial Hæmatoma and Traumatic Aneurysm

A wound of a large artery, or one of its branches, is followed by extravasation of blood into the tissues. If the wound is not large and the surrounding structures are unyielding, the blood may be confined to the immediate vicinity, where it clots, forming a " circumscribed arterial hæmatoma ". In other circumstances the blood may extravasate widely in the cellular planes up and down the limb, producing a large ill-defined swelling, the "diffuse arterial hæmatoma". In either case the greater part of the effused blood coagulates and the wound in the vessel may become sealed off and the whole extravasation gradually absorb. But, if the communication with the vessel remains patent, the central part of the hæmatoma forms a cavity constantly distended by the circulating blood. The interior of the cavity develops an endothelial lining while its walls become thickened and organized. The swelling acquires an expansile pulsation and a systolic bruit, both of which either disappear or are much modified by pressure on the vessel on the proximal side of the sac. This is the " false or traumatic arterial aneurysm ". If the vein accompanying the artery is also involved in the wound, a direct communication between the two may be established—the " aneurysmal varix "; or a sac may form between the two vessels, when the condition is known as " varicose aneurysm ". In each case the peripheral part of the hæmatoma becomes incorporated with the surrounding structures which are matted together in its wall. The change from hæmatoma to aneurysm may come about almost at once, or may be delayed for days or weeks. The process is usually gradual, but may be quite sudden. In the early stages after injury there may be serious interference with the peripheral blood supply, and gangrene may threaten. As time passes, the collateral circulation develops and there is usually greatly increased vascularity, both arteries and veins being affected.

Segmentary spasm: arterial stupor.—As a result of injury to an artery or even in its vicinity the vessel may be thrown into such a degree of spasm that the peripheral pulse disappears. Such spasm may follow manipulation of the vessel or its ligation. As a rule it relaxes spontaneously in about 24 hours. This excess of vasoconstrictor tone may interfere with nutrition in the area supplied by the vessel and may be a contributory cause of gangrene.

Treatment.—It does not respond to morphine or local warmth but when the remainder of the body is heated to about 45° C. vasodilatation is set up in the affected parts but may only be temporary.

Relief may follow blocking of the sympathetic fibres destined for the part. This is accomplished by injecting 2 per cent. Novocain around the pre-ganglion fibres followed by 95 per cent. alcohol or by surgical division or avulsion of the sympathetic trunk.*

Indications for operation.—When the injured patient is seen in favourable surroundings such as a properly equipped hospital provides, it is safer to intervene as soon as possible after the injury If the hæmatoma is increasing or the circulation of the limb is embarrassed, or there are signs of infection, arrangements must be made to operate in spite of the surroundings. So soon as there are definite signs of aneurysm it means that operative intervention will be required, but this may be deferred until there is evidence that the collateral circulation is well developed. On the other hand, when the general condition is improving, the local swelling subsiding and there are no signs of aneurysm, the operation may be indefinitely postponed.

The object of the operation is to expose the injured vessel and either to repair the rent, to apply ligatures, to excise a damaged portion or to bridge a gap by grafting or intubation. Preservation of the vessel need only be considered in dealing with the largest arteries, like the common carotid, the subclavian, the common or external iliac, the femoral or the popliteal. As a matter of actual experience there are very few occasions when conservative measures can be usefully attempted, and the surgeon is usually only too thankful to be able to arrest bleeding by ligation.

Technique.—If seen within the first few hours and the general condition permits, the injured vessel should be exposed by an adequate incision, after the application of a tourniquet or other measures to control hæmorrhage have been taken. The clots, which are easily displaced at this stage, should be completely removed from the cavity in which they lie, and a careful search made for the bleeding-point with the aid of retractors and a good light. To enable identification of the actual bleeding site it may be necessary to temporarily relax a tourniquet and it greatly facilitates matters to employ one of the pneumatic type.

The special method adopted for dealing with the artery will depend upon the nature and extent of the injury. If a wound of a branch of the main artery be found, and there is enough room between the site of the wound and the main trunk the branch may be double ligated and divided. Otherwise the main trunk may be ligated above and below and divided between, or a lateral ligature applied Should the main artery be the source of the hæmorrhage, an attempt should be made to preserve the circulation by arteriorrhaphy, or some other plan having this object in view, to which removal of the surrounding clot, by relieving tension, also contributes.

This operation, especially where the hæmatoma is deeply seated, should always be regarded as serious, and the necessary steps should

* Learmonth, J., 1940, *Ed Med J* N.S., xlvii, 225

be taken to render the patient's condition as favourable as possible beforehand. Blood-transfusion will almost certainly be necessary.

Loss of blood is not the only factor responsible for the tendency to gangrene, as any condition that reduces the blood-pressure, such as shock from multiple wounds or exhaustion, will have the same effect.

Contusions and Wounds of Large Arteries

Contusion.—Contusion of a large artery may throw the vessel into spasm of varying degree of intensity and over a varying length. This spasm may be of short or long duration. The condition "stupeur arterielle" has been made much of by Réné Leriche, in France, and by Sol Cohen,* in this country, who found that traumatic arterial spasm was most likely to result from traction on an artery. Traction initiates the spasm and should therefore be avoided, the artery being carefully handled and disturbed as little as possible. Efforts to relax the spasm by injection of novocain or papaverine, 2·5 per cent., around the artery, sympathetic block or general anæsthesia are rarely successful.

Wounds.—Wounds of large arteries may be of several types: (1) The vessel may be cleanly divided or torn right across in which case the hæmorrhage is much reduced by the retraction and contraction of the ends. (2) A large laceration with continuity completely interrupted, the injury being complicated by destruction of the neighbouring muscular and other tissues. (3) A small wound, caused either by a missile, such as a piece of shell or flying glass, or a stab, with considerable extravasation into the surrounding tissues, and much swelling. (4) Gunshot wounds in which a missile passing close to the main artery has torn off one or more large branches

The surgeon's first aim is to prevent further loss of blood, and it must always be remembered that any bleeding-point which can be reached by the finger is under its control. The *tourniquet* should be avoided when possible, and if it must be employed, it should be removed at the earliest possible moment.

The difficulties attending arteriorrhaphy or the insertion of grafts, ideal methods of dealing with a wounded artery, are considered later. When an important artery is divided completely, and suture is impossible, continuity may be temporarily restored by a vitallium or glass cannula and anti-coagulants administered.

A proximal ligature should never be applied to a main trunk without careful examination of the wounded vessel, unless, indeed, the condition is one of great urgency. If such a ligature is used, care must be taken to apply it as near to the wound in the vessel-wall as possible, in order to avoid interference with the collateral circulation The incision in the skin and soft parts should be longer than for ligature of an unwounded artery, because there may be great difficulty in locating the vessel on account of swelling from extravasation of blood, a difficulty to which absence of pulsation will inevitably add. A free exposure,

* *Lancet*, 1944, i, 1

Relief may follow blocking of the sympathetic fibres destined for the part. This is accomplished by injecting 2 per cent. Novocain around the pre-ganglion fibres followed by 95 per cent. alcohol or by surgical division or avulsion of the sympathetic trunk.*

Indications for operation.—When the injured patient is seen in favourable surroundings such as a properly equipped hospital provides, it is safer to intervene as soon as possible after the injury. If the hæmatoma is increasing or the circulation of the limb is embarrassed, or there are signs of infection, arrangements must be made to operate in spite of the surroundings. So soon as there are definite signs of aneurysm it means that operative intervention will be required, but this may be deferred until there is evidence that the collateral circulation is well developed. On the other hand, when the general condition is improving, the local swelling subsiding and there are no signs of aneurysm, the operation may be indefinitely postponed.

The object of the operation is to expose the injured vessel and either to repair the rent, to apply ligatures, to excise a damaged portion or to bridge a gap by grafting or intubation. Preservation of the vessel need only be considered in dealing with the largest arteries, like the common carotid, the subclavian, the common or external iliac, the femoral or the popliteal. As a matter of actual experience there are very few occasions when conservative measures can be usefully attempted, and the surgeon is usually only too thankful to be able to arrest bleeding by ligation.

Technique.—If seen within the first few hours and the general condition permits, the injured vessel should be exposed by an adequate incision, after the application of a tourniquet or other measures to control hæmorrhage have been taken The clots, which are easily displaced at this stage, should be completely removed from the cavity in which they lie, and a careful search made for the bleeding-point with the aid of retractors and a good light. To enable identification of the actual bleeding site it may be necessary to temporarily relax a tourniquet and it greatly facilitates matters to employ one of the pneumatic type.

The special method adopted for dealing with the artery will depend upon the nature and extent of the injury. If a wound of a branch of the main artery be found, and there is enough room between the site of the wound and the main trunk the branch may be double ligated and divided Otherwise the main trunk may be ligated above and below and divided between, or a lateral ligature applied. Should the main artery be the source of the hæmorrhage, an attempt should be made to preserve the circulation by arteriorrhaphy, or some other plan having this object in view, to which removal of the surrounding clot, by relieving tension, also contributes

This operation, especially where the hæmatoma is deeply seated, should always be regarded as serious, and the necessary steps should

* Learmonth, J , 1940, *Ed Med J N S*, xlvii, 225

be taken to render the patient's condition as favourable as possible beforehand. Blood-transfusion will almost certainly be necessary.

Loss of blood is not the only factor responsible for the tendency to gangrene, as any condition that reduces the blood-pressure, such as shock from multiple wounds or exhaustion, will have the same effect.

Contusions and Wounds of Large Arteries

Contusion.—Contusion of a large artery may throw the vessel into spasm of varying degree of intensity and over a varying length. This spasm may be of short or long duration. The condition "stupeur arterielle" has been made much of by Réné Leriche, in France, and by Sol Cohen,* in this country, who found that traumatic arterial spasm was most likely to result from traction on an artery. Traction initiates the spasm and should therefore be avoided, the artery being carefully handled and disturbed as little as possible. Efforts to relax the spasm by injection of novocain or papaverine, 2·5 per cent., around the artery, sympathetic block or general anæsthesia are rarely successful.

Wounds.—Wounds of large arteries may be of several types: (1) The vessel may be cleanly divided or torn right across in which case the hæmorrhage is much reduced by the retraction and contraction of the ends. (2) A large laceration with continuity completely interrupted, the injury being complicated by destruction of the neighbouring muscular and other tissues. (3) A small wound, caused either by a missile, such as a piece of shell or flying glass, or a stab, with considerable extravasation into the surrounding tissues, and much swelling. (4) Gunshot wounds in which a missile passing close to the main artery has torn off one or more large branches

The surgeon's first aim is to prevent further loss of blood, and it must always be remembered that any bleeding-point which can be reached by the finger is under its control. The tourniquet should be avoided when possible, and if it must be employed, it should be removed at the earliest possible moment.

The difficulties attending arteriorrhaphy or the insertion of grafts, ideal methods of dealing with a wounded artery, are considered later. When an important artery is divided completely, and suture is impossible, continuity may be temporarily restored by a vitallium or glass cannula and anti-coagulants administered.

A proximal ligature should never be applied to a main trunk without careful examination of the wounded vessel, unless, indeed, the condition is one of great urgency. If such a ligature is used, care must be taken to apply it as near to the wound in the vessel-wall as possible, in order to avoid interference with the collateral circulation. The incision in the skin and soft parts should be longer than for ligature of an unwounded artery, because there may be great difficulty in locating the vessel on account of swelling from extravasation of blood, a difficulty to which absence of pulsation will inevitably add. A free exposure,

* *Lancet*, 1944, i, 1.

moreover, renders it less likely that the surgeon will overlook a divided branch of the main vessel that may have retracted. It should be borne in mind that the general condition is often serious from loss of blood, and that transfusion plays an important part in the management.

A careful search for the actual bleeding-point is essential, and a ligature should never be applied to the main trunk until there is certainty as to the origin of the hæmorrhage, for a large branch may be the source while the main artery itself is intact.

A large vessel such as the external iliac may be *punctured* with a surgical needle, an accident which has occasionally happened during an operation for the radical cure of hernia. If recognized at the time, the bleeding can be arrested by finger-tip pressure which may be

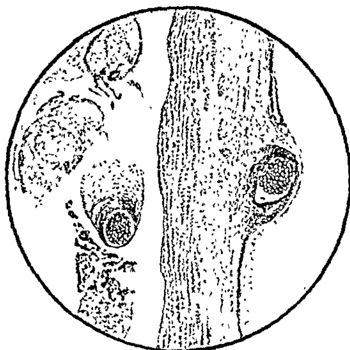


Fig. 229.—Fine silk suture suspended in lumen of abdominal aorta of dog.

On examination 25 days later, a firm intima-like lining covered the suture (After Hamilton Drummond and Shaw Dunn)

enough to allow contraction and permanent occlusion of the puncture. Failing this a single stitch may be applied in the adventitia across the puncture, or a purse-string suture may be required If oozing persists, a patch of fresh muscle or a piece of fibrin film or "gel foam" held in position for a moment will adhere and almost certainly prove effective When delay has occurred, a hæmatoma will probably have formed and must be dealt with as indicated in the previous section.

Arterial suture.—Suture of arterial wounds is by no means new, for it was practised by Surgeon Lambert, of Newcastle-upon-Tyne, as long ago as 1759 Vascular suture is an essential part of the operations for vessel grafting, for embolectomy and aneurysmorrhaphy.

To secure successful results the following conditions are essential: (1) perfect asepsis; (2) a clean-cut wound in the vessel-wall, without bruising; (3) absence of tension at the line of suture; (4) sufficient time to allow the surgeon to carry out the operation thoroughly; (5) a minimum amount of surgical trauma; (6) special precautions against clotting in the wounded vessel. It will be seen from this enumeration why so few injuries lend themselves to repair by this method.

A great variety of suture material has been employed, but at the present time most surgeons rely on fine black silk fitted to eyeless needles; this may be obtained ready sterilized in tubes of liquid paraffin. It is well to have sutures threaded both on straight and curved needles. Fine-toothed dissecting forceps, vessel clamps with spring or rubber-covered blades, fine sharp scissors and a fine, thin-bladed very sharp scalpel for trimming the vessel ends should also be ready. The straight needles are usually manipulated with the fingers, but the small curved needles require a fine needle holder, such as may be used for cleft palate work or nerve suture. It should be of a pattern with which the surgeon is thoroughly familiar. A pair of fine artery forceps serves the purpose quite well. The whole field must be kept moist with isotonic (3·8 per cent.) sodium citrate solution. Some authorities think it essential to prevent the suture material coming in contact with the circulating blood, but experimental work and the scrutiny of healed anastomoses have shown that suture material abutting on the vessel lumen, whether paraffin-coated or not, does become clothed with an intima-like covering which makes the internal surface of the suture line perfectly smooth and even. (Fig. 229.)

Arterial clamps should have non-serrated blades of the bow type and with a sufficient degree of "spring". But clamps are not easy to apply in deep wounds, and a fine rubber tube passed under the vessel and gently drawn towards the surface will often suffice. For larger vessels it may be necessary to cross the ends of the rubber tube in front of the vessel and to fix them temporarily with an artery forceps, or by ligature.

Technique.—These operations have often been carried out under local analgesia but, unless there is some special contra-indication, general anæsthesia is advisable. The limb should be exsanguinated and a tourniquet applied; it is then placed in a suitable position so that the surgeon can work comfortably and unimpeded. The incision should be so planned as to give the most direct exposure, and of such length that the use of retractors is reduced to a minimum. It follows that whenever possible it should be placed over the line of the artery and it will usually be several inches long, depending on the depth of the artery and on the muscular development of the part. Of course it does not follow that the length of artery exposed will be of great extent, but the easy access to the two inches or more required will depend upon the free incision of the superimposed parts. The vessel

moreover, renders it less likely that the surgeon will overlook a divided branch of the main vessel that may have retracted. It should be borne in mind that the general condition is often serious from loss of [illegible]

certainty as to the origin of the hæmorrhage, for a large branch may be the source while the main artery itself is intact.

A large vessel such as the external iliac may be *punctured* with a surgical needle, an accident which has occasionally happened during an operation for the radical cure of hernia. If recognized at the time, the bleeding can be arrested by finger-tip pressure which may be

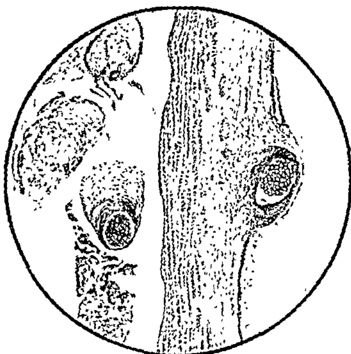


Fig. 229.—*Fine silk suture suspended in lumen of abdominal aorta of dog.*

On examination 25 days later, a firm intima like lining covered the suture. (*After Hamilton Drummond and Shaw Dunn.*)

enough to allow contraction and permanent occlusion of the puncture Failing this a single stitch may be applied in the adventitia across the puncture, or a purse-string suture may be required. If oozing persists, a patch of fresh muscle or a piece of fibrin film or "gel foam" held in position for a moment will adhere and almost certainly prove effective. When delay has occurred, a hæmatoma will probably have formed and must be dealt with as indicated in the previous section

Arterial suture.—Suture of arterial wounds is by no means new, for it was practised by Surgeon Lambert, of Newcastle-upon-Tyne, as long ago as 1759 Vascular suture is an essential part of the operations for vessel grafting, for embolectomy and aneurysmorrhaphy.

To secure successful results the following conditions are essential: (1) perfect asepsis; (2) a clean-cut wound in the vessel-wall, without bruising; (3) absence of tension at the line of suture; (4) sufficient time to allow the surgeon to carry out the operation thoroughly; (5) a minimum amount of surgical trauma; (6) special precautions against clotting in the wounded vessel. It will be seen from this enumeration why so few injuries lend themselves to repair by this method.

A great variety of suture material has been employed, but at the present time most surgeons rely on fine black silk fitted to eyeless needles; this may be obtained ready sterilized in tubes of liquid paraffin. It is well to have sutures threaded both on straight and curved needles. Fine-toothed dissecting forceps, vessel clamps with spring or rubber-covered blades, fine sharp scissors and a fine, thin-bladed very sharp scalpel for trimming the vessel ends should also be ready. The straight needles are usually manipulated with the fingers, but the small curved needles require a fine needle holder, such as may be used for cleft palate work or nerve suture. It should be of a pattern with which the surgeon is thoroughly familiar. A pair of fine artery forceps serves the purpose quite well. The whole field must be kept moist with isotonic (3·8 per cent.) sodium citrate solution. Some authorities think it essential to prevent the suture material coming in contact with the circulating blood, but experimental work and the scrutiny of healed anastomoses have shown that suture material abutting on the vessel lumen, whether paraffin-coated or not, does become clothed with an intima-like covering which makes the internal surface of the suture line perfectly smooth and even. (Fig. 229.)

Arterial clamps should have non-serrated blades of the bow type and with a sufficient degree of "spring". But clamps are not easy to apply in deep wounds, and a fine rubber tube passed under the vessel and gently drawn towards the surface will often suffice. For larger vessels it may be necessary to cross the ends of the rubber tube in front of the vessel and to fix them temporarily with an artery forceps, or by ligature.

Technique.—These operations have often been carried out under local analgesia but, unless there is some special contra-indication, general anæsthesia is advisable. The limb should be exsanguinated and a tourniquet applied; it is then placed in a suitable position so that the surgeon can work comfortably and unimpeded. The incision should be so planned as to give the most direct exposure, and of such length that the use of retractors is reduced to a minimum. It follows that whenever possible it should be placed over the line of the artery and it will usually be several inches long, depending on the depth of the artery and on the muscular development of the part. Of course it does not follow that the length of artery exposed will be of great extent, but the easy access to the two inches or more required will depend upon the free incision of the superimposed parts. The vessel

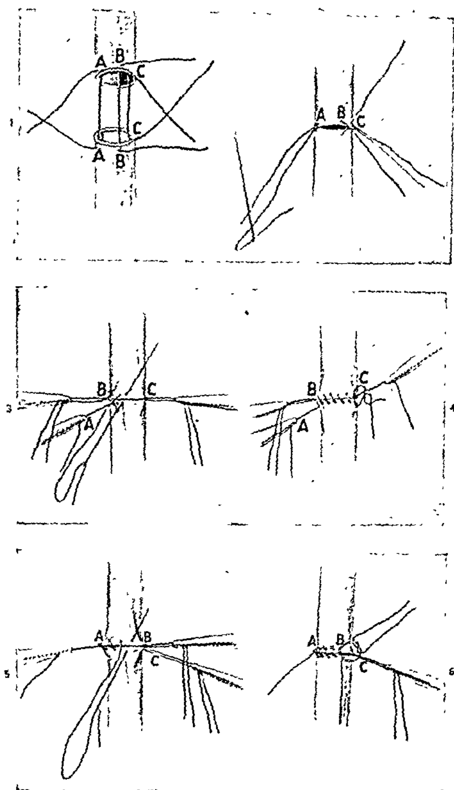


Fig. 230.—Arterial suture by Carrel's method.

1 Three equidistant stay-sutures in position 2 Making vessel triangular to aid suture. 3 and 4. Suture of second side of triangle with vessel partially rotated 5 and 6. First side of triangle being sutured with continuous suture through all coats of vessel. (*See also* Fig 231.)

is carefully isolated, the greatest care being taken to reduce handling to the minimum. It must be raised from its sheath sufficiently to allow arterial clamps or rubber slings to be applied above and below the site of proposed suture. It assists the separation of the vessel from its sheath if the cellular bed in which it lies is distended by *infiltration* with normal saline solution. Only blunt dissection is required, and the actual lifting of the vessel is done by slings or by fine mouse-tooth forceps taking hold of the edges of the wound, which in any event will be trimmed. Great care must be taken to preserve all branches. Vascular clamps must include the whole width of the vessel in their grasp and they must be very lightly and gently applied. When they

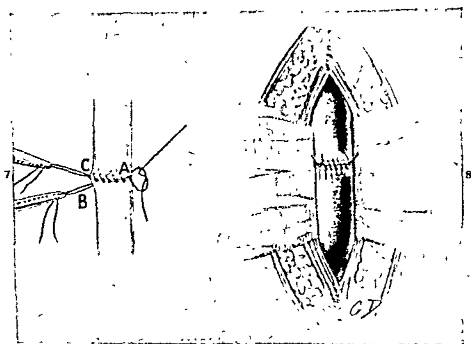


Fig. 231.—Arterial suture by Carrel's method

7. Third side of triangle; vessel completely turned; rotation of vessel is reversed to bring this side of triangle into view. 8 Suture of artery completed

are securely in position, the tourniquet may be removed. Longitudinal and oblique wounds may be closed by a continuous suture. Slight narrowing of the lumen is not necessarily an obstacle to success, though pronounced narrowing encourages thrombosis. In transverse wounds involving more than one-third of the circumference the vessel should be completely divided and restored by end-to-end suture.

Of all the methods introduced for end-to-end anastomosis of artery or vein, Carrel's classical suture still holds the field. The chief points are : (1) The application of three stay-sutures making the vessel at points of proposed union into an equilateral triangle. (Fig. 230, 1, 2.) (2) Each side of the triangle is then secured by a continuous suture with a tie at each stay-suture. (Fig. 230, 3, 4.) (3) All sutures pass through all coats of the vessel-wall, including the intima, which is everted.

The actual method of application of these sutures is best seen from Fig. 230, 5, 6, and Fig. 231, 7, 8. In the opinion of some surgeons two stay-sutures are sufficient.

Needless to say, great care should be taken to avoid damage to the vessel, and this refers not only to the ends, but also to the portion over which clamps are applied during the time of suture.

In end-to-end suture the most essential part of the operation, whatever method be adopted, is the complete removal of the adventitia from the vessel ends. If this structure is left *in situ*, the ends remain ragged, and while the continuous suture is being inserted a portion of



Fig. 232a.—Arterial suture.
Cut ends of artery showing protruding adventitial coat.



Fig. 232b.—Arterial suture.
Shows method of drawing adventitia over cut end of artery preliminary to removal.

the torn adventitia is likely to be caught and dragged into the lumen, inevitably leading to clotting. (Fig. 232a.)

The best method is to pull the adventitia gently over the open lumen of the artery (Fig. 232b), and then to cut it off flush with the edge of the vessel with fine scissors. The adventitia, when pulled upon, is easily stretched, and, when cut across, retracts well above the divided end of the vessel (Fig. 233.)

The artery should be well washed with the citrate solution to remove all blood. It is of the greatest importance to keep the structures moist and warm during the process of suture and this is done by dropping

citrate solution, at a temperature of 100° F., over the wound throughout the operation. After the suture is complete, the *distal* clamp should always be loosened first, allowing blood to flow through the anastomosis from below, and therefore at a much lower pressure than if the proximal clamp were removed. In consequence the surgeon is better able to deal with any leak that may occur in the suture line. If the leak be of any size the distal clamp should be immediately reapplied, and a single suture put through all the coats at this point. Light finger-tip pressure on a small piece of gauze held against the vessel after the removal of the distal clamp will allow the necessary clotting to occur at the stay-holes, where there is nearly always a leak

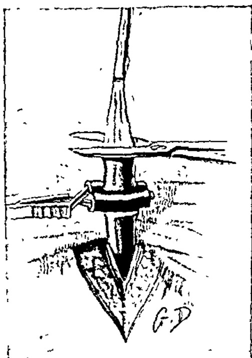


Fig. 233.—Arterial suture.
Removal with fine scissors of protruding adventitia.

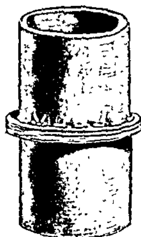


Fig. 234.—Shelton Horsley's flange method of arterial suture.

when first the clamps are removed. Oozing from the suture line may be controlled by fibrin film or " gel foam " wrapped around the vessel.

When the suture line seems reasonably well sealed the next step is the removal of the proximal clamp; this should be done slowly, while at the same time gentle pressure of dry gauze should be applied at the line of suture. It is important not to apply pressure too forcibly nor for too long a time, for fear of inducing clotting at the site of anastomosis. The gauze is cautiously lifted and the anastomosis inspected. If the suture line is sound and fairly dry and the pulsation passed normally to the distal segment, probably all will be well, but there is a risk of thrombosis at the site of anastomosis and it may be well to administer heparin in the hope of preventing this.

Shelton Horsley* described another method, in which he applied three stay-sutures followed by a mattress-suture, introduced by two

* *Surg., Gyn., Obstet.*, May, 1914, xviii, 536.

needles; he thus raised a flange round the divided ends of the vessel, the cut edges being left uncovered by the sutures. (Fig. 234.) The advantage claimed for this method is that the intima is thereby more nearly approximated, and that there is a minimum amount of suture material exposed in the lumen of the vessel. A similar plan, but using only one needle, is recommended by Learmonth (1940).

Completely divided vessels may be difficult to repair by end-to-end suture as they stretch to a very limited extent and are often anchored by branches which it may be unwise to divide. Grafts may be used (p. 560).

Lateral or small transverse wounds that are clean-cut are the most suitable injuries to suture, and give uniformly good results, in the absence of infection. Such injuries, most commonly caused by sharp knives, as in stab-wounds, or by flying glass, are dealt with by the application of proximal and distal clamps and suture The adventitia is removed and, the vessel having been washed clean with warm citrate solution, the rent is repaired by one continuous suture which passes through all the coats of the vessel.

A small hole in a large vessel caused by the division or avulsion of a lateral branch may be closed in the same manner. Persistent oozing may be arrested by placing a small piece of fresh muscle or one of the fibrin products over the area of repair and pressing it into position for a minute or two with the tip of the gloved finger.

Suture of wounded blood-vessels.—The experiences of the war of 1914–18 repeated in 1939–45 proved that primary vascular suture for gunshot wounds was rarely practicable. This was due (1) to the great extent of damage done to the vessel-walls by the impact of the missile; (2) to the infection of the operative field, (3) to the lack of time and, often, of suitable environment. In injuries to main arterial trunks in the upper limb, ligation of the bleeding vessel is often all that is necessary, provided no great damage to the collateral circulation has occurred, and this should be remembered when arterial suture is under consideration. Similar conditions may obtain in civil life, especially with railway or severe motor accidents Practically any of the main limb vessels may be ligated without risk of gangrene, but it is otherwise in severe injury to the soft parts which may have seriously damaged the smaller vessels on which the collateral circulation depends. In the hope of saving such a damaged limb the surgeon may be justified in trying primary arterial suture but in the immediate past the results have been disappointing. Chemotherapy has been of great assistance to the surgeon by enabling him to prevent or control infection while heparin has helped to diminish the risk of thrombosis

TRANSPLANTATION OF SEGMENTS OF BLOOD-VESSELS

It was long ago demonstrated by Carrel* that segments of blood-vessels may be successfully transplanted from one animal to another of the same species. Further, it has been shown by numerous experi-

* *Journ Amer. Med. Assoc*, 1907, lx, 225

mentalists that cannulæ made of various materials can be introduced between the ends of divided arteries in animals with successful results. Guthrie transplanted a portion of the vena cava of a dog, preserved in 2·5 per cent. formalin for sixty days, between the divided ends of the common carotid artery of another dog. At the end of twenty-three days the vessel was laid open, and the lumen of the transplanted segment was found to be patent and capable of carrying on the circulation; there was slight thickening, but otherwise the graft looked normal. This clearly proved that a preserved venous graft may adequately serve the mechanical function of an artery over a period of more than three weeks. The bridging of an arterial defect by the transplantation of segments of blood-vessels has now become more than an experimental procedure, and venous grafting has been performed many times with success. It is obvious that a fresh graft is the best, and that it should be supplied from the patient's own vessels. A venous graft is employed, as its removal does no damage to the circulation; the internal saphenous vein will be found useful for the purpose. The graft should be placed in the reverse position, so that any valves present will not impede the circulating blood. Such grafts have been used after excision of aneurysms to bridge a gap between vessel ends which could not be approximated for direct suture. They have also been employed in wounds of large vessels, and in involvement of large arteries in resection for malignant disease. (*See also* p. 560.)

Hogarth Pringle,* of Glasgow, recorded two cases of aneurysm treated by this method, after resection of the sac In one case (left popliteal aneurysm), he was unable to join the cut ends of the artery, so he employed 4 in. of the internal saphenous vein from the opposite thigh as a graft, and by this means, using Carrel's method of suture, he restored the circulation. Three months later the patient returned to work, and when seen again nine months after the operation there was pulsation in the popliteal graft which could be seen and felt, and both pulses at the ankle joint were of the same volume. This man worked regularly until he died from heart disease three years and three months after the operation. He always declared that the limb operated upon was as good as its fellow. The grafted area examined after death showed a patent lumen of rather larger diameter than the adjacent artery. The other case was that of a blacksmith who sustained an injury to the brachial artery, just above the elbow joint. At operation, five weeks later, the artery was found to have been split longitudinally for an inch This portion was excised, and a graft from the internal saphenous vein implanted. The result was successful, and the patient returned to work in fourteen weeks, with the circulation through the injured artery restored, for pressure over the grafted area immediately arrested the radial pulse This man also declared that the limb upon which the operation had been performed was as good as its fellow. A year afterwards he joined the army and served in Gallipoli, where he was killed in action

* *Lancet*, June 28, 1913, i, 1795.

The same procedure was carried out by Lexer* after excision of an axillary aneurysm, and the result was also successful.

Arterial Grafting

Arterial grafting has recently undergone considerable development and Dubost and his associates (1952),† Brock (1953)‡ and others have resected aneurysms and constrictions or thrombosed parts (as in Leriche's disease) of the aorta and established continuity with preserved arterial grafts It has been demonstrated that arterial grafts do not live as such but act as scaffolding and are gradually replaced by the tissues of the host. Early results have been satisfactory; no long term results are yet available.

The grafts are preserved homografts, and arterial banks in which segments of aorta and other vessels are stored so as to be instantly available when required, are being established in surgical centres

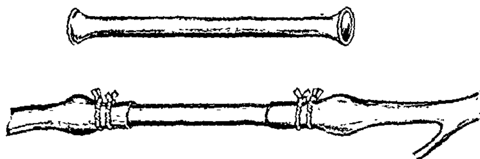


Fig. 235.—The cannula as used by Gordon Murray and Janes. (*Brit Med Journ* July 6th, 1940)

throughout this and other countries. Grafts, which are obtained aseptically, may be preserved either in a balanced solution kept at 3 or 4° C. from which they may be used for a period of up to 8 or 9 weeks, or else by rapid freezing in vacuo at —70° C. By the latter method the grafts may be preserved indefinitely at room temperatures. The suturing of an arterial graft of appropriate size between the resected ends of the parent vessel is by the now well established methods already described (p. 553)

Artificial Canalization—Tuffier's Method

This method was suggested by the French surgeon Tuffier for dealing with cases where the wound of the vessel is so extensive as to make suture impossible; it consists in the introduction of a cannula of special metal or plastic material between the divided ends of the torn vessel. It is admittedly only a temporizing plan which has often proved disappointing because of thrombosis in the lumen but this is reduced with the aid of heparin. It is employed especially in cases of injury of large vessels, such as the carotid, the femoral, or the popliteal arteries, where

* *Arch. klin Chir*, 1907, lxxxiii, 459
† Dubost, C, Allary, M, and Oeconomos, N, *Arch Surg*, 1952, lxiv, 405
‡ Brock, R C, *Proc R Soc med*, 1953, xlvi, 115

primary ligature may lead to gangrene before the establishment of a satisfactory collateral circulation. (Fig. 235.)

The cannulæ are made with a flange at each end, and in various sizes. The torn vessel is temporarily occluded with Crile's clamps and its lumen washed free of blood ; the damaged ends are trimmed up, the tube is inserted and tied over the flanges with fine silk ; and the soft parts are then lightly sutured over the tube and artery. The cannulæ will have rendered their maximum service in from four to six days and may then be removed.

These tubes were extensively used during the 1914-18 War and there can be no doubt that they proved of value, as they often enabled some blood to circulate pending the establishment of the necessary anastomotic circulation. It is a question how long they remain patent after introduction. In many cases there was rapid clotting in the tube and the adjacent segments of artery. The late Sir George Makins stated that he had always seen clotting in the tube at the end of four days, and strongly advocated its removal, and ligature of the proximal and distal ends of the vessel, at this time. In one case under the care of Tuffier the circulation was kept up through the femoral artery for a period of ten days (but this was admitted to be most unusual) and Sir C. Gordon-Watson recorded a case where the circulation was kept up through the popliteal artery for five days. Nevertheless, before the use of heparin it was the general experience that clotting occurred within twenty-four hours. Having served its purpose, the tube is removed and the vessel-ends tied.

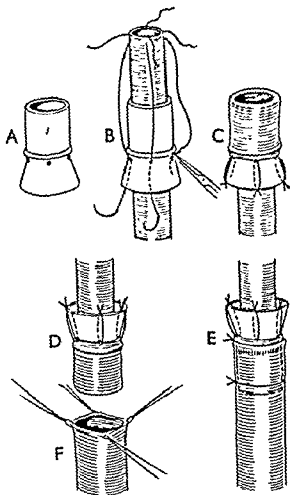


Fig. 236.—A, vitallium tube. B, vein threaded through tube. C, eversion of vein over tube; guide sutures seamed through the tube. D, insertion of vein with tube into the artery which is held open by four sutures. E, join seamed by fine silk thread.

Repair of Vessels over In-dwelling Cannulæ

A. H Blakemore* and his associates have used vitallium tubes as cannulæ for joining the arterial ends to an interposed piece of vein.

* J Amer. Med Ass., 1945, cxxvii, 685

Using guide sutures, the vein ends are threaded through the vitallium tubes and everted over the ends so that the endothelial surfaces of vein and artery are in apposition. They are secured by five silk threads tied around the tubes which are ridged to take them (Fig. 236).

This method involves leaving the cannulæ *in situ*. The technique is sufficiently indicated by the figures. The plan has been extensively employed in making porto-caval unions. While the method is highly ingenious it has the grave disadvantage of a permanently rigid area at the actual site of union and in practice thrombosis has often occurred. Efforts have been made to devise cannulæ which having served their purpose will completely absorb. Experts in vascular surgery much prefer direct suture methods even when the vessels are small.*

LIGATION OF MAIN ARTERIES

Nowadays these operations are not often required and it is unnecessary to describe them in minute detail.

The **principal indications** are :—as a preliminary to other operations and especially amputations near the trunk, and the *removal of large vascular malignant tumours* ; *for the treatment of hæmorrhage that has resisted other means of arrest* ; as one of the methods for the treatment of aneurysm ; and to influence favourably some pathological condition such as the hæmangiomas.

Technique.—The following questions invariably arise :—

1. The material for the ligature. Silk, thread or catgut may be used If catgut the chromicized variety is to be preferred the size depending on the vessel, for small vessels No. 0, for vessels like the femoral No. 1, and for the common carotid or larger arteries No. 1 or No 3.

2. How tightly the ligature is to be applied. Theoretically it is necessary only to occlude the vessel and not to rupture the intima, but in actual practice it is difficult to know when the requisite amount of pressure has been employed and if the ligature is not sufficiently firmly applied to rupture the intima, the circulation may become re-established. To remove all doubts in the matter, it is highly desirable to tie the artery in two places at an interval of half an inch and divide the vessel between. When the resulting open vessel ends are very obvious it is an additional security to close them by suture. In this way the surgeon can be absolutely sure that the circulation through the vessel will be permanently interrupted. This step probably has the additional advantage of interrupting the vaso-constrictor pathways which may be so much stimulated by simple ligation as to set up peri pheral arterial spasm, thus interfering with the development of th collateral circulation. By allowing the ends to retract it also does aw with longitudinal tension and makes occlusion easier and more se and, even in the presence of sepsis, this method is considered safer

any other. An additional and important advantage is that the pulsation in the divided distal segment of the artery is diminished and clot is not therefore likely to be driven off as an embolus, an important consideration in the case of the carotid (Fig. 237).* Every effort should be made to have the ends buried in the soft tissues and, when this does not occur as the result of retraction, neighbouring muscles should be drawn over them. When it is necessary to ligate a branch near a main trunk it is most important to leave as long a stump as possible, and especial care should be taken to cover the ligated vessel with muscle or other tissue, such as fascia or a neighbouring salivary or other gland.

3. Treatment of the vein. Formerly it was emphasized that the greatest care should be taken to avoid injury to the vein, but it is now recognized that it is safer to ligate the vein at the same time as the artery. By this means *there is less likelihood of gangrene.* Some doubt has recently been expressed about the truth of these statements, but there is much to support them and even if ligation of the vein only plays a minor part in securing better nourishment of the limb it can at least be urged that this step does no harm.

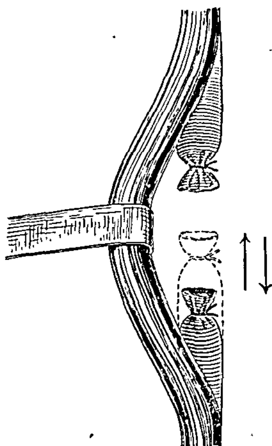


Fig. 237.—To ensure that circulation is permanently interrupted, the vessel is tied in two places and divided between the sutures. The ends are allowed to retract thus doing away *with longitudinal tension.*

The principles of the operation are as follows :—

(1) The incision should be made in such a way as to secure the most direct exposure of the artery and with as little retraction and manipulation as possible.

(2) The *guide to the artery* is its known anatomical course, and at each step the definition and recognition of structures which have the most direct relationship to it. Each vessel has some landmark which ought to be known and which is recognized as the "rallying point" for that particular vessel. It is essential that the incision should be of sufficient length ; the most frequent difficulties are due to inadequate exposure. T[illegible] in the cadaver, for the puls[illegible]

When the [illegible] this should be

* Lambert Rogers, *Brit J. Surg*, 1947, xxxv, 43, *Lancet*, 1949, i, 949.

just beyond the origin of a large branch rather than at some distance beyond the branch with a resulting dead end (Fig. 238). The full force of the arterial pressure is thereby directed to expanding the branch and opening up the collateral circulation and not uselessly distending a blind pocket of the main artery (Holman*).

(3) The vessel must be isolated from surrounding structures. When the artery is exposed it should be very gently raised in its bed with an aneurysm needle passed under it. It may then be gently drawn towards the surface so that it may be safely cleared from surrounding structures. Great care must be taken in dealing with an artery that is obviously in an advanced state of atheroma, for such vessels may be very brittle and have been known to tear across.

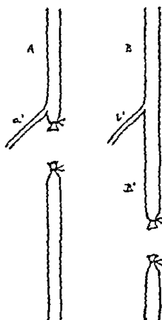


Fig. 238.—A, Ligature just beyond a branch. B, Ligature more remote from the branch. The pressure in branch a' is found to be higher than that in branch b'.

(4) The ligature must be passed from the most important structure. For this purpose an aneurysm needle is very useful, and whether this is passed threaded or unthreaded depends on the accessibility of the situation. If, as recommended, the artery is to be divided between ligatures, the proximal ligature should be tied first. If there is likelihood of the ligature being blown off the proximal end of the artery, a second one transfixing the vessel just beyond the first ligature is a safeguard and may be employed with advantage on such a vessel as the common carotid.

(5) The vein should be tied separately; silk is the best material for ligating veins; it has a better bite and a very fine size can be used.

(6) The wound should be carefully closed, muscle and fascia being drawn together so that the vessel ends are not in direct line with the skin-wound; in most situations this naturally follows. It is better to avoid drainage whenever possible.

(7) The dressing must be light and loose and the limb must not be encircled with bandages or strapping.

The Care of the Parts after Ligation of a Main Artery

The limb must be kept at rest at heart level or slightly elevated and in the most comfortable position, such as lying on its side on a soft pillow. The dressing should be light and [illegible] bandages. When the patient is restless, [illegible] two or three loose ties around the pillow and over [illegible]

* Surg. Gyn. Obst., 1944, xcviii, 275.

used. Sometir ... [illegible] ...nded but it must only be loosely

The limb sh... [illegible] ...ry protected by a sterile towel which can readily be turned back for inspection, and is exposed to room temperature which should not be higher than 60° F. It may be kept cool by an electric fan. The comfort of the patient must be studied and for this purpose small doses of morphia, $\frac{1}{8}$ grain or less, may be administered every few hours, not as a routine but as required. If the circulation is being well maintained all will be well. Of course the general condition must be attended to, the patient having as much fluid as is desired and also food. If in spite of these measures there is anxiety about the nutrition of the part the first requirement is to ensure that the vessels are filled and blood transfusion most quickly fulfils that end. This keeps up the volume of circulating fluid and fills the collaterals and capillaries. The patient should be kept warm to relax the peripheral vessels.

In emergencies, like war-time injuries, large and repeated blood transfusions will probably be required at first, followed by a drip. Vaso-dilation in the affected part can best be brought about by heating the other parts of the body, especially the hands and arms, and as Learmonth has suggested electrically heated gloves and armlets are excellent. Food with some alcohol will also help. If the parts do not respond to these measures the outlook is bad but sympathectomy may help; sometimes it is considered wise to carry this out as part of the primary operation but it is not necessary to make it a routine.

Aluminium Bands for the Occlusion of Large Arteries

These were used by W. S. Halsted, of Baltimore, in 1906; the method has since been modified and simplified by Matas and Allen. It was introduced for the temporary or trial occlusion of large vessels, but it can be used instead of the ordinary ligation. The bands are made of aluminium and are perfectly smooth and with rounded edges. They are 6 in. long and of varying widths from $\frac{5}{16}$ inch, and thin enough to be bent and compressed round the artery by the fingers. The vessel is exposed in the ordinary way, as if for ligation, and the band, fashioned like an aneurysm needle, is passed around it, and then gently compressed about the artery with the fingers until the pulse on the distal side becomes imperceptible. The excess is then cut away with stout scissors. Any desired degree of occlusion can be secured and the band may be left *in situ* or subsequently removed if it is desired to re-establish the circulation. The idea is attractive but there is always the fundamental objection to leaving unabsorbable foreign bodies in the tissues.

Simultaneous Ligation of Arterial and Venous Trunks

This question has engaged the interest of surgeons ever since this plan, previously introduced by Oppel, was brought prominently before the profession at the time of the 1914–18 war. Experimental evidence has been advanced both for and against this procedure (*see* p. 563).

The Danger of Arterial Ligature in Cases of Arterio-venous Communication

It cannot be too strongly emphasized that to ligate the main artery proximal to a large arterio-venous fistula is almost certain to lead to peripheral gangrene. The reason for this is that the arterio-venous shunt short circuits the peripheral circulation to such an extent that when the main arterial stream is interrupted there is an insufficient blood flow to the periphery. Such cases must be treated by either (1) closure of the fistula or (2) quadruple ligation, i.e. closure of both artery and vein above and below the fistula or (3) excision of the fistula.

Ligation of Particular Arteries

The analysis of cases by Prof. William Sheen* and of a more recent series by Sir Gordon Gordon-Taylor† (in 52 collected cases there were 30 recoveries and 22 deaths—a recovery rate of just over 57 per cent.) and the observations of the late Sir Charles Ballance‡ lead to the conclusion that there are certain cases of **aneurysm of the innominate artery** which are suitable for proximal ligation. This is to be preferred to distal ligation which though an easier operation may produce a diverticulum of the aorta and so increase the pressure within it. To guard against recurrence, Sheen recommended simultaneous ligature of the common carotid. This is also a protection against cerebral embolism by way of it from clot in the aneurysm. The type of aneurysm most suitable for proximal ligature is one that arises at the bifurcation of the innominate artery.

Ballance held that a portion of the sternum should be removed when performing this operation, and pointed out that, from an anatomical point of view, the ligation of the innominate artery is a cervical operation which should not present any great difficulty. The trachea is the guide to the artery. An incision from four to six inches is made along the anterior border of the sternomastoid and carried down on to the sternum. The carotid sheath is exposed and opened and that vessel followed down to the innominate. The internal jugular and innominate veins lie to the outer side and so do the vagus and the pleura. The aneursym needle is passed from the outer side The trunk of the innominate should be gently lifted forwards with the instrument as it is advanced to the inner side. Usually thick braided silk has been used for the actual ligature, care must be taken not to tie it so tightly as to divide the coats of the vessel. Sometimes a double ligature of rather thinner silk or thread used as a stay knot (Ballance) has been employed.

If there is any doubt about the adequacy of the ligation, the common carotid and if accessible also the vertebral should be tied. Sheen recommended a vertical incision from the cricoid down over the sternal notch, and did not consider it necessary to divide or remove bone.]

Several methods of bone removal may be used. Sir William

* *Annals of Surgery*, 1905, xlii, 1. † *Brit J. Surg.*, 1930
‡ *Brit J Surg.*, Jan., 1922, ix, 436

Wheeler recommended that the inner end of the clavicle and the upper part of the right half of the manubrium sterni should be divided and turned up with the sterno-mastoid, being replaced at the conclusion of the operation. The manubrium may be split down its centre by means of a sternal chisel (illustrated in Chapter XXXVII, Vol. II) and the right and left halves freed apart by a trypan rib spreader. This gives a good view of the base of the innominate artery, or the inner third of the clavicle and a portion of the manubrium sterni may be removed. It is not necessary to replace the bone, the subsequent movement of the arm being excellent. These methods may convert an almost impossible feat into a workmanlike undertaking.

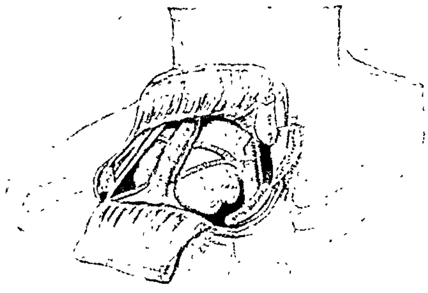


Fig. 239.– Exposure of the innominate artery by section of the clavicle and manubrium sterni.
(Drawing lent by Sir W. Wheeler.)

The **subclavian artery** is easily tied in its third part. This operation may be required as a preliminary to interscapulo-thoracic amputation. The classical route is very satisfactory if attention is paid to all the details, i e. the shoulders must be elevated on a hard cushion or sandbag and the arm well pulled down by the side. The incision should be almost the whole length of the clavicle. Superficial veins are caught and divided. The outer border of the scalenus anticus and the lowest trunk of the brachial plexus are the important guides to the artery.

Exposure of the first and second parts is admittedly difficult, but the difficulties largely disappear with a wide exposure. The skin incision must extend from the inner border of the sterno-mastoid, right across the base of the neck as far as the *anterior border* of the trapezius muscle on the same side. If at any stage further *room* should be required, another incision may be made along the anterior border of the sterno-mastoid and carried down over the upper part of the sternum.

The sterno-mastoid muscle is completely divided just above the clavicle and the inner third of that bone is removed by separating the structures close to the bone, taking care to make the separation subperiosteal on its deep aspect. The bone is cut across with any convenient type of small saw. If a Gigli saw is employed great care must be taken to pass it behind the clavicle very close to the bone. The final stage of division is completed with bone forceps. With the fragment held in strong forceps, its inner end is disarticulated; the claviculo-sternal joint is very strong and it facilitates matters to detach the meniscus at the upper border of the articular surface of the clavicle. At the inner border of the wound the sterno-hyoid and the sterno-thyroid muscles may be divided. With blunt gauze dissection the parts can be well exposed on the left side. A sharp look-out must be kept for the thoracic duct, which can always be easily identified as thin-walled, beaded, pale and without pulsation. If punctured it should be ligated and if divided both ends must be tied. The jugular and subclavian veins can be readily exposed and gently thrust aside. It may be a great help to doubly ligate and divide the internal jugular, great care being taken to leave sufficient of the vein beyond the ligatures. It must be remembered that the apex of the pleura covered by Sibson's fascia which is often thin extends up into the neck behind the subclavian, and the artery must be very gently separated from it. After ligation of the artery or its branches as may be required, the wound is closed. If the divided sterno-mastoid can easily be approximated to muscle remnants on the sternum or to the ends of the infra-hyoid muscles so much the better, but this is not essential. It is sufficient to suture the skin carefully with the deep fascia and platysma. For some days the arm is kept supported on a pillow or by the side. The functional recovery is quite remarkable. A posterior approach to the first part of the left subclavian has been described by A. K. Henry* and has every appearance of being satisfactory.

Ligation of ductus arteriosus.—This is considered on p. 628.

Ligation of the common carotid artery.—The risk of cerebral symptoms, sometimes fatal, is a danger but these are unlikely to occur in a fit subject with a normal blood pressure.† When possible the operation should be performed under local analgesia and the effects of temporary occlusion studied on the patient by electro-encephalography and by measuring with a dynamometer the strength of the opposite hand grip. The artery should always be divided to prevent subsequent embolism (*see* p. 563). Electro-encephalographic studies have shown that it is inadvisable to ligate the corresponding internal jugular vein.

Technique.—The vessel is most conveniently ligated just above the omo-hyoid. The incision should be a transverse one, as indeed all incisions in the neck should be, with its centre lying over the anterior

* "Exposures of Long Bones and Other Surgical Methods," 1927, Bristol: Wright.
† *Medical Press*, 1953, 230, 56.

border of the sterno-mastoid. For the inexperienced, however, and in an emergency a long incision in the line of the artery may be easier, its only detriment is the subsequent obvious scar. The first guide is the anterior edge of the sterno-mastoid; in muscular subjects this completely covers the artery and must be well retracted. The approach is through the space of Valpeau, i.e. *outside* the pre-thyroid muscles and between them and the deep surface of the sterno-mastoid. The carotid sheath is freely opened, and the vein will be found overlying the artery. It must be carefully isolated for some distance so that it can be drawn outwards without risk of being torn. The vagus nerve lies posteriorly between the artery and vein; it must be exposed so that it may be avoided. There will be no difficulty in isolating the artery, for the purpose of passing the ligature, if it is gently drawn towards the surface, the surrounding structures being thrust aside by blunt dissection.

External carotid.*—A curved incision crossing the anterior border of the sterno-mastoid should commence opposite the angle of the jaw and extend to the lower border of the thyroid cartilage. The artery is much higher in the neck than is usually supposed. It is easy to mistake the internal for the external carotid, and the true guide is the presence of branches on the latter. The vessel is often obscured by the common facial vein, which may be very large. It should either be drawn gently downwards and forwards, or divided between ligatures. The carotid is to be sought between the anterior border of the sterno-mastoid and the posterior belly of the digastric muscle. The hypoglossal nerve is usually seen crossing the field just a little below the latter muscle.

The **lingual artery** is nowadays seldom tied as a preliminary to operations on the tongue. The classical exposure through a small incision may be very difficult. The best plan is to make a large curved incision such as is used for excision of the glands in the submaxillary region. With this exposure, the anatomical landmarks are easily identified.

The **axillary** artery can be exposed in the greater part of its length by an incision in the axilla along the course of the vessel. With the arm held at right angles to the body and careful retraction, this presents no difficulty Ligation of the third part of the subclavian can usually take the place of ligation of the first part of the axillary and is much easier and more satisfactory. When the tissues are disturbed and displaced, as they may be in traumatic aneurysm, there need be no hesitation in making an incision directly over the line of the artery, from the middle of the axilla to the centre of the clavicle. Both the pectoral muscles can be divided in this line and, if necessary, the clavicle. With the arm drawn away from the side and the shoulder allowed to fall back, the exposure is very free. Afterwards the ends of the clavicle

* The same exposure may be used to ligate the internal carotid It should be remembered that in many subjects, particularly women, the division of the common carotid is higher in the neck than is classically described There is a greater risk of cerebral complications after internal than after common carotid ligation.

should be drilled and fixed together with strong catgut or wire, and the muscles carefully repaired with stout catgut. *If approximation of* the divided bone is difficult the central portion may be removed and the ends left free. Early movement is encouraged and the ultimate functional result is satisfactory.

The **common** and **internal iliac** arteries may be approached by the trans-peritoneal route. Good anæsthesia and the high Trendelenburg position greatly facilitate the operation. A median incision is best, and should extend from just above the umbilicus to the pubes. The peritoneum over the artery must be picked up before being incised, and *there should be no hesitation in dividing it for 2 or 3 in. The ureter* tends to adhere to the peritoneum, but it can always be identified by its *position and the fact that it vermiculates at intervals and when touched.* The vein must be carefully separated from the artery before passing the ligature. When it is decided at what point the artery is to be tied, it can be held by forceps and gently drawn inwards, the vein being carefully thrust aside by gauze stripping. It is not easy to tie the internal iliac artery, and great care must be exercised, for it hugs the pelvic wall and is intimately connected with the vein.

The **external iliac** can also be tied by the *intraperitoneal route*, but in most cases this is not necessary. It can be reached conveniently by making the classical oblique incision in the iliac fossa ½ in above Poupart's ligament. This incision must stop short of the internal abdominal ring on the one hand and the deep circumflex iliac artery on the other. After incising the muscles and the transversalis fascia, the peritoneum can be easily stripped up and the artery reached extraperitoneally. *The lowest part of the vessel can also be exposed by an oblique incision* just below Poupart's ligament. The common femoral is identified and, with the thigh slightly flexed, the inguinal ligament can be drawn upwards with a strong narrow retractor, allowing the iliac vessel to be exposed and tied

The **femoral artery** and its branches present no special difficulty provided adequate incisions—six or more inches in length—along the line of the artery are employed. When the intervention is for primary hæmorrhage it is imperative to expose the bleeding point, which is often *at the site of the origin of a branch* In all circumstances both ends of the injured vessel must be secured Gunshot wounds in these areas are dangerous and there is risk of subsequent gangrene. The question of artificial canalization should be borne in mind (*see* p 560). In the upper three-quarters of the thigh the incisions should be on the anterior aspect in the line of the vessels. In the lower quarter the incision should be medial, along the line of the adductor tendon. The sartorius is exposed, freed and retracted *laterally or medially*, whichever is the more convenient The roof of Hunter's canal is freely opened and, if necessary, the vessel is traced down beyond the adductor into the upper part of the popliteal space.

The **popliteal vessels** may be exposed by a long, slightly oblique incision extending from a hand's breadth above the centre of the popliteal space, slightly on the inner side, to a hand's breadth below that point in the middle line. The first part of the artery is best exposed from the inner side of the thigh. The knee being flexed and abducted an incision is made parallel with and a little behind the tendon of the adductor magnus, from the junction of the middle and lower thirds of the thigh to the adductor tubercle, care being taken to avoid the great saphenous vein. The artery lies embedded in fat close to the femur and is best approached between the adductor magnus and the sartorious which is drawn backwards.

The **gluteal and sciatic vessels.**—In dealing with wounds or small aneurysms or doubtful lumps which require exploration, direct incision over the buttock may suffice. When there is great vascularity, as in large aneurysms or new growths, the hæmorrhage following direct incision may be appalling, and no incision should be made until a temporary ligature has been placed on the common iliac artery. The abdomen having been temporarily closed, the patient is then turned over so that the region of the lesion on the buttock may be explored. This is best done by a very free incision along " Lizar's upper line " which runs from the posterior superior iliac spine to the tip of the great trochanter. In muscular subjects the skin incision may well be of this length The gluteus maximus is divided in the same line, which corresponds with the direction of its fibres. As soon as its substance has been traversed, the cellular plane between it and the deeper muscles will be apparent. By blunt dissection and good retraction, the pyriformis will readily be exposed, with the gluteal vessels in the region of its upper border and the sciatic below. To secure a sufficient exposure it may be necessary to detach some part of the origin of the gluteus maximus from the crest of the ilium and the great sacro-sciatic ligament. After the lesion has been dealt with and the vessels secured at the site, the wound must be packed while the temporary ligature is loosened. If, after removal of the packing, inspection shows that the hæmorrhage is completely arrested, the buttock wound may be closed, after which the patient is laid on the back and the anterior wound closed On the other hand, small persistent bleeding in the buttock may be traced to its source and dealt with directly But if the bleeding cannot be arrested or if it is profuse, the temporary ligature must be again tightened while the internal iliac is secured by permanent ligature, after which the temporary ligature may be removed and the abdomen closed. The internal and not the common iliac artery should be ligated, as gangrene in the limb has been known to follow ligation of the common artery. Attention must then be given to the toilet of the buttock wound. These interventions are serious, much care must be taken to guard against infection, the necessary movements must be carried out, slowly and deliberately, and time allowed for the patient to rest between stages. Two operators

may work together, one dealing with the abdomen and the other the buttock. Of course, arrangements for blood transfusion must be in readiness or employed throughout.

The **posterior tibial artery** presents features of special interest. Most surgeons recognize the difficulty of dealing with hæmorrhage in wounds of this vessel. These cases, when seen a few hours after injury, show a tense, brawny, painful swelling of the whole of the calf, often with free hæmorrhage from the entry or exit wound. Immediate operation is demanded, not only to avoid further loss of blood but to lessen the risk of septic complication and gangrene due to pressure of the extravasated blood.

In the presence of much extravasation throughout the muscular planes of the back of the leg, it is often very difficult to find the bleeding-point. The usual incision for ligation of the vessel is made along the

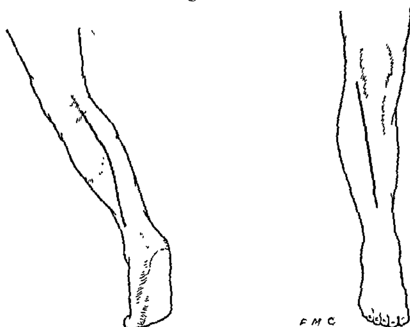


Fig. 240.—Lines of incision for ligation of anterior and posterior tibial arteries.

inner tibial border, ½ in. behind the bone. After division of the skin, the deep fascia is incised and the inner edge of the gastrocnemius defined and drawn backwards. The soleus muscle is then divided about ½ in. from its attachment to the edge of the tibia and, when this is complete, the intermuscular septum or fascia covering the deep flexor muscles is exposed and followed up to the middle of the leg. The parts being then carefully retracted, the vessel is found lying on the tibialis posticus muscle. This is the ordinary textbook operation, but it will be found difficult and unsatisfactory in the cases under consideration The best and most direct route (Guthrie's method) is by a long incision down the middle of the back of the calf, dividing the skin, the superficial and deep fascia, the gastrocnemius and the soleus; the incision should incline inwards, to end midway between the tendo

Achillis and the internal malleolus. (Fig. 240.) With a finger as a guide, the two heads of the gastrocnemius can be separated, and the soleus divided vertically in the middle line. By retraction of the edges of the divided muscles the posterior tibial vessels will be exposed.

The advantages of this incision are directness of approach, better exposure in dealing with bleeding-points, and more efficient drainage if necessary. Further, should the peroneal artery prove to be the source of hæmorrhage, and not the posterior tibial, the injured vessel is more easily found.

The upper third of the **anterior tibial** artery is difficult to expose on account of the upper part of the fibula. The incision should extend along the posterior border of the biceps tendon, around the neck of the fibula and down over the anterior compartment of the leg. The external popliteal (common peroneal) nerve should be deliberately exposed over the length of the wound so that it can be drawn aside out of harm's way. The outer head of the gastrocnemius and the soleus may be completely divided and, if necessary, a section of the upper third of the fibula excised; it is not necessary to replace the bone. The anterior tibial in the middle third of the leg can readily be exposed if the incision employed is adequate (Fig. 240).

Secondary Hæmorrhage

Secondary hæmorrhage usually takes place between the seventh and tenth day after injury or operation. Almost invariably it is the result of wound sepsis but is sometimes actually precipitated by the pressure of a hard drainage tube in contact with the vessel. The sepsis is often of a mild type and may be associated with the separation of sloughs. There are often premonitory signs, with very moderate pyrexia. The patient looks ill, is nervous and anxious and is often getting thinner. There may be unexplained pain in the wound, bright red stains on the dressings or the appearance of small clots or brisk, slight bleeding the " red signals ".

Treatment.—It must be emphasized that the correct procedure in [illegible] attack on the source of the bleeding [illegible] through healthy tissue proximal to [illegible] o accentuate the importance of this first principle. There are two exceptions to this rule of direct attack as Hailes* has pointed out: (1) hæmorrhage from branches of the internal iliac artery in the buttock; (2) hæmorrhage from some branches of the external carotid artery. In these two exceptions immediate ligation of the internal iliac and the external carotid, respectively, is indicated.

Frequently, when secondary hæmorrhage occurs in compound fracture or large granulating wounds, the actual source of the hæmorrhage cannot be determined, on account of inflammatory swelling.

* *Aust. N.Z. J. Surg.*, 1946, xvi, 39.

Here the best results will be secured by packing the wound with gauze after first removing old clots and débris with a sharp spoon. The gauze should be left *in situ* until it loosens spontaneously. There are cases, for instance in hæmophilia, in which secondary hæmorrhage is very difficult to control and in which the ordinary accepted methods fail to bring about arrest. In these circumstances the value of *turpentine as a hæmostatic should be remembered.* It is applied as a pack of strips of lint soaked in the turpentine but from which the excess has been squeezed. Clots and débris must first be removed from the wound which is then plugged in the depths with the strips. The skin around the wound should be protected from the blistering effects of the turpentine with Vaseline and dry gauze. *Mild pressure is applied* and the dressing is not disturbed for some days when it loosens spontaneously, a curiously slimy discharge being thrown out. The method is most effective, and septic wounds usually clear up well as a result. In all these cases the resources of antibacterial therapy and blood [illegible] ust be remembered that in [illegible] measure. [illegible] and, as soon as possible after the hæmorrhage, the wound should be explored and search made for the bleeding-point under a general anæsthetic and in a good light. Very often this will be found to be the distal end of the vessel, but both ends must always be ligatured. When the bleeding is from a branch near a main trunk, the parent vessel should usually be ligated above and below the bleeding-point. The parietal wound should be lightly sutured or left open and packed with gauze.

Should hæmorrhage recur, a further attempt may be made to secure the bleeding-point, but this may prove well-nigh impossible. In these circumstances the main vessel must be tied above in healthy tissue. As a rule, the results are good, especially in upper-limb wounds, where the brachial and axillary arteries are concerned.

Removal of Emboli from Arteries

Cardiac disease is the commonest source of a peripheral embolus. Of recent years the diagnosis of embolic block has been followed increasingly by the operation of arteriotomy for removal of the embolus. The Scandinavian surgeons have taken a leading part in this development, and in 1936 Einar Key* of Stockholm was able to state that 382 embolectomies had been performed in Sweden with a very encouraging degree of success. Their lead has been followed by surgeons throughout the world. While in many cases gangrene may be averted, it must be realized that the patients are often the victims of cardiac or general vascular disease and that late deaths from these causes are not uncommon. Patients have recovered, however, and continued in good health for years, even after multiple embolectomy. French surgeons, following the teaching of Leriche, hold that the impaction of the embolus causes widespread peripheral vascular constriction

* *Brit Journ Surg*, 1936, xxiv, 350.

and for that reason they maintain that arterectomy is the best way to deal with the condition. In the upper limb the collateral circulation develops so satisfactorily that spontaneous recovery may usually be expected. Antispasmodic drugs and heparin sometimes have a considerable effect, but in elderly subjects the arteries are less resilient and gangrene is more likely to follow and if there are no definite signs of returning circulation in about six hours, operation is indicated. When the embolus lodges in the abdominal aorta, or anywhere beyond, gangrene nearly always follows and operation is imperative.

Clinical features.—It should be realized that the onset is nearly always sudden and that the main features are usually pain, pallor, cold with numbness, paresis and absence of arterial pulsation. The affected limb is marble cold and both looks and feels dead.

Localization.—Emboli usually lodge where vessels divide (Fig. 241), but secondary thrombosis may spread from the original site. It is important to endeavour to determine the site of lodgment before cutting down on the vessel; the site of the initial pain is the surest indication. On general principles this will be somewhat above the site of evident arrest of circulation and may be expected where the vessels divide. The pulsation in the vessel ceases just below the impaction, but the vessel may not be readily accessible for palpation or, in any event, the pulsation may be weakened by the poor general condition of the patient. When the vessel is accessible the actual embolus may be felt and that area may be acutely tender.



Fig. 241.—A typical "riding" embolus at the bifurcation of the carotid.

(Reproduced by permission from D. L. Griffiths, *Lancet*, 1938, Dec. 10)

Time for intervention.—If an attempt is to be made to remove the embolus, it should be as early as possible. The chances of success are good up to 10 hours, but rapidly diminish afterwards, and are slender in 24 hours. The intervention must be looked upon and managed like an acute abdominal emergency.

Preparatory treatment.—Since some cases recover spontaneously and others respond to heparin those seen within an hour or two of onset should have "first aid" and be carefully observed while a decision as to operation is being made or preparations for intervention carried out.

The measures recommended are:—(1) Administration of 10,000 units of heparin; (2) Keep the threatened part cool, 15–20° C.; (3) Relieve pain—and; (4) Induce sleep (both of which measures tend to promote

vaso-dilatation); *(5) Withhold digitalis* unless essential to combat cardiac failure.

If operation is decided on the anti-coagulant effect of the heparin may be discontinued by the intravenous injection of protamine sulphate.*

Technique.—Local or spinal anæsthesia should be employed and great care exercised in what may be an extensive dissection. The first indication is to expose the vessel, and for this purpose it is necessary to make a sufficiently long incision. The actual length will depend on the anatomical build of the individual and on the accuracy of the localization of the obstruction. When the vessel is exposed the site of the embolus may be perfectly obvious, or may be in some doubt. In the former case a definite bulging may be noticed in the vessel and there may be quite forcible pulsation which stops at this point. On the other hand, though pulsation may be feeble it may be readily felt up to the suspected area while being much less marked below. In these circumstances it is highly probable that the embolus is causing only partial blocking. When the site has been located the vessel must be isolated and means must be taken to control the circulation, either by clamps or by rubber slings. The latter are generally most convenient and are very efficient, but when the arterial wall is degenerated it is most important that they should not be pulled on at all forcibly or it may be torn through. The next step is to open the vessel by an incision about ½ in. long. This is better made at the lowest part of the embolus or even just below it. When the lumen of the vessel is opened it should be gently held apart with fine guide sutures; while the sling on the distal side is kept in position, the proximal sling is carefully released in the hope that the force of the current will drive out the embolus. If it does not do so, then the obstruction should be very gently milked down with the fingers towards the opening in the vessel and assistance may be gained by an aspirating cannula or sucker, the lumen of which is only just introduced into the arterial opening. It is very much better to remove the embolus in this way than to introduce forceps, or any instrument which might damage the intima. When the obstruction has been cleared on the proximal side, the distal sling should be released in the hope that the return current may be unimpeded or may wash out any small portions of embolus that have been displaced from above or secondary thrombus that has formed beyond the embolus. It is not enough for the blood to well up; it should spout with the normal pulsations. Of course, if the lumen of the vessel cannot be freed by external manipulation then forceps or, better still, a small scoop with a blunt end may be introduced into the vessel, not so much with the idea of scooping out the embolus as in the hope that it may be loosened and broken up so that it can be washed out by the blood stream. After removal of the obstruction heparin is most useful. The vessel is closed with fine vascular silk. If it is not

* Learmonth, *Ed Med J*, Vol. LV, p 449, 1948.

possible to clear the site of the obstruction it is better resected so as to limit the spread of thrombosis and to suppress its vaso-spastic influence.

In the after care it is necessary not to constrict the limb in any way. It should be comfortably laid on a pillow, slightly flexed, and kept cool. The patient's body should be heated to relax the peripheral vessels. In most favourable circumstances the condition of normal vascularity returns immediately, but in some cases this may be delayed for several hours, and even in the most successful cases there may be pain for two or three days. Secondary embolus, either in the periphery of the vessel operated upon or emboli in other vessels, must be looked for. Cases are on record where multiple interventions have been followed by success, and there is no reason why the surgeon should be deterred, especially since the introduction of heparin.*

Mortality and after results.—In the 382 Scandinavian cases 59·4 per cent. died in hospital, 22·5 per cent. were completely cured, with restoration of the limbs, and 18·1 per cent. were cured after gangrene and amputation. It is significant that of those operated upon within 10 hours 55 per cent. regained normal circulation.

Embolism of the abdominal aorta.—The clinical picture of a patient with a known cardiac disability seized with lower abdominal pain referred down the limbs and followed by sudden paraplegia is very striking. Without operation the prognosis is almost hopeless. There are two ways of dealing with the saddle embolus of the aortic bifurcation either by direct attack on the aorta or indirectly by opening the femoral or external iliac artery and dislodging the clot by milking or intravascular probing. If a direct attack is made the bifurcation is exposed and tapes placed around the aorta and its two branches. Those on the iliacs are not tied at first to avoid breaking up the embolus. An incision is then made into the aorta on its antero-lateral aspect at its junction with the right common iliac artery, the clot removed and the opening closed by a running mattress suture of fine silk. Keely† of Chicago (1948) has reported a successful case in which one patient, a woman of 53 years, was alive and well 23 months after operation. There have been over 40 other reported cases. Learmonth (*loc. cit.*) had three recoveries in four cases and both Ewing's‡ patients survived operation. If the indirect method is employed the best plan is to expose both femoral arteries just below Poupart's ligament. On one side the vessel is surrounded by a rubber sling by which the artery can be temporarily occluded, preve[illegible] the periphery On the oppos[illegible] is exposed by the oblique [illegible] With the fingers in the extraperitoneal tissues an attempt is made to milk down the embolus from the aorta into the femoral of the same side. From this vessel it is removed by direct incision. Endovascular

* MacFarlane, *Brit Med J*, 1940, i, 371.
† *Ann Surg.*, 1948, cxxviii, 257.
‡ Ewing, M R, *Brit J. Surg*, 1950, xxxviii, 44.

manipulations with instruments should be avoided as much as possible. After the main clot has been removed the opposite femoral should be examined and any clot which has been driven into its lumen must also be removed by direct incision. Movement usually comes back to the limbs a few hours after operation, but it may be 24 hours or more before full sensation returns and several days before pain completely disappears. Occasionally ischæmic contracture has followed after either approach. Anticoagulant therapy should be continued for 7–10 days with digitalis if there are signs of cardiac failure.

Pulmonary Embolism

It was in 1908 that the German surgeon Trendelenburg described the first operation for this condition carried out on the human being. In October, 1930, Gunnar Nyström* of Upsala published no fewer than ten cases in which he had operated; five patients survived, and of these two made a permanent recovery. In 1939 Ivor Lewis† published the first British success, but the operation is now obsolete and only of historical interest. The cause of the condition is still somewhat obscure but clotting from which the embolus arises (phlebothrombosis) usually occurs in the intramuscular calf veins. These veins should not be subjected to prolonged compression by allowing the calves to lie directly on the operation table. A soft pillow or sorbo rubber cushion should always be placed under the Achilles tendons of both legs to elevate the calves clear of the table. This procedure and early movement combined with deep breathing are the surest methods of prophylaxis. Since in a massive embolus death usually takes place within ten minutes, opportunity for surgical intervention can seldom occur and the correct procedure is the immediate administration of full doses of heparin (300 mgm) Success has followed this procedure which prevents the propagation of the clot into the other pulmonary artery.

Disobliterative Endarteriectomy

For many years the idea of restoring chronically blocked or obliterated arteries to functional activity has occurred to those interested in vascular surgery. In the past attempts have been made to recanalize such vessels by removing thrombi and other obstructions by intubation, the use of spoons and probes and other instruments. With the guidance of arteriography and the use of anti-coagulant therapy these methods were revived with some success by dos Santos and Leriche The plan of longitudinal incision into an artery with deliberate removal by dissection of the blocked area and the inner coats followed by reconstruction of the vessel wall with its lumen has been devised and practised under the inspiration of Louis Bazy‡ of Paris and carried on by his pupils §

The intervention is limited to examples of old emboli which have become fibrosed and organized and obliterative arteritis of the non-

* *Ann Surg*, 1930, xcii, 498
† *Lancet*, 1939, i, 1037
‡ *Mem. acad Chir*, Paris, lxxiv, 104–9
§ Reboul and Laubry, *Proc Roy. Soc Med*, 1950, xliii, 547

acute variety in which the collateral circulation is deficient and in which other treatment has failed. For the most part only large vessels like the abdominal aorta and the major arteries of the limbs have been tackled.*

Technique.—Anti-coagulant therapy plays an essential part in the intervention and the use of heparin to prolong the coagulation time to 15 minutes, or longer during the operative period, is essential. The affected portion of the vessel is exposed by an adequate non-hampering incision and a strip of tissue about 5 cm. wide is removed right down to the vessel the adventitia being carefully preserved. A special clamp (devised by Bazy) gently occludes the artery at points just above and below the area to be cleared. The wall of the artery is incised longitudinally down to the thrombosed area and a plane of cleavage is sought between the elastic limiting layer and the media. The dissection is carried on in this plane with curved scissors up and down the artery to above and beyond the obstructed area which is then completely cored out, rather suggesting the removal of a bone sequestrum. Extensions of the obliterative process into collaterals have to be removed and when bleeding occurs such vessels must be temporarily occluded by clamps or ligatures previously placed in position. The extremities of the freed portion must be cleanly cut across, any tags or fringes being removed. The clamps are released to confirm that the lumen is free and when that is assured they are closed again and the suture of the incision in the vessel is commenced. During the operation the whole of the exposed area, the instruments and the surgeon's gloves are kept moist with heparin solution (500 mgm. of heparin to 100 ml. of saline solution). The incision in the artery is repaired by two continuous sutures of 6/0 black silk on eyeless needles. The first takes up the limiting layer and the second supports this with adventitia and areolar tissue. The distal and proximal clamp are then slowly and deliberately removed. Any oozing from the suture line usually ceases as the reconstructed vessel distends with blood but if necessary an additional suture may be applied here and there. The parietal incision is closed without exerting pressure on the sutured artery and a safety drain is inserted to give exit to any blood or serum collection that might do so.

Heparinization is continued after the operation, the dose being gradually reduced allowing the coagulation time to return to normal in about twelve days.

Natural repair by restoration or regrowth of the intima with its endothelial lining is said to occur and to be complete in about a month. Impending gangrene has sometimes been warded off and the distal parts have recovered and function has been restored.

This is advanced and ambitious surgery but of course it does not touch the underlying causative factors from a continuance of which disappointment may arise.

* More recently arterial grafting has replaced such methods with most surgeons (*see* p. 560).

ANEURYSM

Arterio-venous Aneurysm

In civil practice this condition is but rarely met with, whereas every great war is followed by a spate of aneurysms of this type.

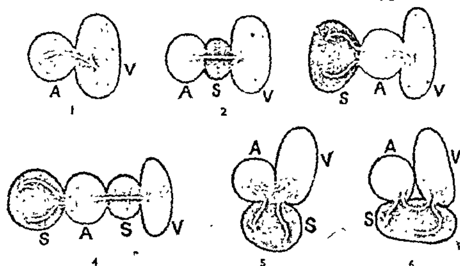


Fig. 242.—Arterio-venous aneurysms. (*After Makins.*)

1. Aneurysmal varix. 2. Arterio-venous aneurysm. 3. Arterial aneurysm with aneurysmal varix. 4. Arterial and arterio-venous sac. 5. Arterio-venous sac with common opening into artery and vein. 6. Arterio-venous sac with separate openings into artery and vein.

Makins (" Gunshot Injuries to Blood-vessels ") examined the records of 272 cases of traumatic aneurysm, the result of war wounds, admitted into the London hospitals, and found that 120 were arterial, 100 arterio-venous, and 52 aneurysmal varix.

Matas, on the other hand, believes that aneurysmal varix is the most common arterio-venous lesion, the two vessels communicating by a direct fistulous opening. He found that, as a rule, when an adventitious sac existed it was situated either in front of or behind the vessels rather than between. With regard to the relation of the vessels to one another and to the adventitious sac (Fig. 242), these authorities are in agreement. Whether an arterio-venous aneurysm (fistulous aneurysm) is a varicose aneurysm or an aneurysmal varix does not much matter and the types set out in Fig 242 are only of academic interest. The important fact is the communication and from a practical point of view what really matters in a case of traumatic aneurysm is whether it is or is not fistulous in type. If it is, then arterial ligation is contra-indicated; if it is not, it is usually safe to ligate the artery.

Differential diagnosis of fistulous and non-fistulous aneurysms.—The two varieties can be differentiated by the character of the bruit, which is continuous in the case of the arterio-venous type and systolic in those non-fistulous traumatic aneurysms in which a bruit is present and by the presence of Branham's sign, that is, slowing of the pulse which occurs when the artery proximal to the aneurysm is compressed in the case of the fistulous variety.

It is sometimes stated that the arterio-venous communications have a tendency to contract, and that they may even close spontaneously.* Makins recorded a case of arterio-venous aneurysm of the innominate artery and vein which, after a period of five years, underwent a spontaneous cure. Barber and Madden† have also reported one in which spontaneous cure occurred in six months' time in the case of an arterio-venous aneurysm between femoral vessels in the groin of a negro who had been stabbed there. This tendency to natural cure is also shown by animal experimentation, and, further, it occurs in cases where arterio-venous anastomoses have been carried out for senile gangrene. In the well-established condition which usually comes before the surgeon, and particularly if the fistulous opening is large, natural cure is most unlikely. The condition may be expected to get steadily worse and, when large vessels are involved, the heart enlarges and gradually becomes decompensated and there may be tachycardia and dyspnœa on the slightest exertion. Holman (1937–9) has drawn special attention to this aspect. In very early cases, where there is hope of spontaneous cure, the area may be supported by an elastic bandage while all exertion is avoided. Surgical treatment will usually be necessary on account of (1) pain, (2) buzzing noises, as when the lesion is in the neck, (3) obstruction to the peripheral venous circulation, (4) increase in the local distension of the vein, (5) disturbances of the eye in internal carotid and [illegible] [illegible]) cerebral symptoms [illegible] size with aching and [illegible] embarrassment.

Arterio-venous aneurysms occur most frequently in the carotid, femoral, popliteal, axillary and tibial vessels.

Treatment.—In all cases of traumatic aneurysm it is advisable to delay operation for 3 to 6 months if possible in order to give time for the collateral circulation to develop and become established. The danger of hæmorrhage at the operation should be fully realized and complete command of the arterial circulation is essential. If an efficient tourniquet can be applied without encroaching on the operative field, this will usually suffice, but when there is great venous engorgement both a proximal and distal tourniquet should be employed.

In other circumstances the main supplying vessels must be deliberately exposed on either side of the aneurysm so that temporary ligatures can be applied. Where the aneurysm is large and the collateral circulation well developed, the main trunk must be temporarily secured at a point above the origin of the principal collateral branches. For instance, in high femoral or inguinal aneurysm the external iliac must be controlled, and this will require an abdominal approach. Even after temporary ligation of the common iliac, when the sac is opened there may be free hæmorrhage through the anastomosis of the epigastrics. In axillary aneurysm the third or even the first part of the subclavian will require temporary ligation to control

* I have seen this come about in a traumatic case.—L.C.R.
† *Arch. Surg.*, 1943, xlvii, 364.

the free anastomosis coming through the scapular vessels. As Matas* said, the essential is "The preliminary control of the circulation by obtaining a mastery of the great regional trunks in order not only to control the direct circulation in the aneurysm but that which is supplied by the collateral vessels."

The operations available.—Proximal ligation of the artery in fistulous cases is almost never permissible, for it is likely to be followed by gangrene. In these circumstances the blood which finds its way through the collateral vessels returns to the trunk *via* the communication in the vein; the periphery is short-circuited and vascular starvation results. The principle of operation must be to close the fistula by a direct attack whenever this is possible.

The following methods are available:— (1) Restorative—endo-aneurysmorrhaphy; (2) Quadruple ligation of artery and vein; (3) Excision.

Whichever operation is carried out it is incomplete unless the communication between the arterial and venous systems is eliminated. In all peripheral arterio-venous aneurysms of moderate size excision or quadruple ligation is effective. When the great vessels near the trunk are involved the reconstruction method would appear to be most desirable, but it is in just these cases that the difficulties are greatest and the surgeon is often glad if he can safely terminate the operation by multiple ligations or excision.

Endo-aneurysmorrhaphy.—This method, which may be described as the Matas-Bickham operation, dates back to 1904, and has since been more fully described and strongly advocated by Matas in numerous communications to the literature

One of his earlier papers† records his experience of 12 arterio-venous injuries treated by it with a very large measure of success, and well indicates the scope of the measures he recommends. Of the cases, 1 involved the common carotid artery and internal jugular vein, 1 the external iliac vessels, 8 the common and superficial femoral vessels, 1 the peroneal, and 1 the subclavian artery and vein. These cases were all treated by opening the venous sac and suturing the orifice or orifices of communication. In varicose aneurysm the approach to the opening was through the false sac, and in aneurysmal varix through the dilated vein In 1946 Elkin‡ quoted 106 cases of war aneurysm; 61 were treated by the Matas operation and 45 mostly by excision All were cured and there were no deaths and no gangrene. (Fig. 248.)

The intravenous and intrasaccular suture at the expense of the vein is not always as ideal as it may appear. Paterson Ross§ as the result of experience with cases in the recent war found that obliteration of the vein in cases in which the femoral vessels were involved produced pain and a bursting feeling, particularly around the ankle, and in some cases œdema and swelling These symptoms do not arise if quadruple

* [illegible] (19[illegible]) "S[illegible] of Operative Surgery," Vol I, p 269

ligation and resection of the fistula are performed or if the artery is ligated above and below the fistula and the vein preserved.

In endo-aneurysmorrhaphy for aneurysmal varix, the particular method by which the vein is to be treated can be determined only by the condition found at the operation. The ideal plan is that which aims at the preservation of both vessels, more especially in the neck; but if the artery can only be sutured at the expense of the vein, this may be done, particularly in the case of the carotid. Part of the vein can then be used to reinforce the line of suture like a patch.

Matas, describing the technique of closure of the arterio-venous fistula through the vein, lays stress on the importance of avoiding injury to the endothelial lining.

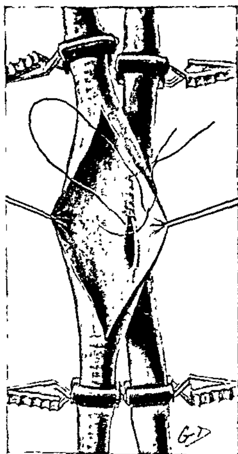


Fig. 243.—Matas-Bickham operation, with preservation of both vessels, leaving no knots in lumen of vein.

Technique.—The steps of the operation are: (1) Exposure of both vessels by a long incision, and their isolation above and below the communication. (2) Occlusion of the vessels above and below with vascular clamps or rubber slings. (3) Removal of the sac, by careful dissection in arterio-venous aneurysm, and in both vessels exposure of the aperture of communication. (4) Repair of the holes in each vessel by suture. (5) Release of tourniquet or clamps and punctilious control of hæmorrhage. (6) Closure of incision.

In carrying out this suture the needle is first passed through the fibrous tissue which binds the artery and vein together at one end of the fistulous opening and on the adventitial aspect of the vessels, care being taken to avoid penetration of the intima of either vessel. The knot is tied so that it remains outside the lumina of both artery and vein. The suture is then passed obliquely from without through the vein wall close to one end of the opening, the extreme edges of which are brought together by a fine continuous suture passed through the intima and media until the other end of the opening is reached, when the suture is brought out and secured in the fibrous adventitious structures, as at the commencement. (Fig. 243.) The continuous suture is thus within the interior of the vessels but the knots are outside Should the dilated vein have developed into a definite sac, it may be necessary to remove it, when the opening in the artery may be closed through the space thus made, but this is

unusual, as a simple dilatation of the vein is much more common. If this method cannot be readily carried out, the vein and artery may be deliberately separated and the aperture in each closed from the outside. In some few cases it has been possible to ligate off the communication.* The next step is to remove the tourniquet or cautiously loosen the *temporary ligatures. Very often there is considerable bleeding from* small branches, which have been unobserved, or from hidden communications. Such hæmorrhage may be alarming and the tourniquet or temporary ligature may have to be tightened again. When all vessels have been caught and the field is quite dry the wound may be closed. Drainage should be avoided.

Ligation of both artery and vein on the proximal and distal side of the lesion—**quadruple ligation**—is the operation most commonly employed and has proved satisfactory. There is no single operative procedure which is applicable to all cases of arterio-venous aneurysm.

The ideal intervention is often not practicable. The results of restorative methods carried out under war conditions have often proved disappointing. Many careful, conscientious surgeons have embarked on an operation with the set purpose of repairing both artery and vein, but on account of the difficulties have had to be content, or have been glad to be able, to carry out the quadruple ligation. In most such cases both surgeon and patient have had every reason to be content with the final result. As a rule the aneurysm has been cured and the limb restored to completely functional activity.†

In performing the quadruple ligature operation it is important to secure as many of the collateral vessels connected with the sac as possible, as these may gradually enlarge and interfere with the *permanency of the cure. If ligation must be used, rather than reconstruction, the best plan is to combine it with excision of the affected* parts of the vessels. If the latter step proves unwise because of hæmorrhage, fibrosis, implication of nerves, etc., the proximal artery should be divided just beyond the ligated point.

In arterio-venous aneurysm of the neck (communication between the carotid and internal jugular vein), every effort should be made to carry out reconstruction, because of the great importance of the cerebral circulation.

In conjunction with quadruple ligation, excision of the sac, or varix, is a safeguard against possible recurrence

Each case must be carefully studied and dealt with according to the *indications and the conditions found, and in actual practice an* operation commenced with the full intention of conservative reconstruction often ends in one of multiple ligation probably combined with excision. Those with most recent experience have been driven to the same conclusion (Learmonth‡). The treatment of arterio-venous aneurysms may thus be summarized:—

* I have been able to do this successfully in an axillary case in a middle aged woman.—L C R.
† Philip H Mitchiner, *St Thomas's Hospital Gazette*, Vol 38, No 4, July, 1940
‡ *Proc Roy Soc Med*, June, 1946, Vol 39, viii, 488–90 (Sect of Surgery, pp 36–38).

(1) Wait 6 months unless there are contra-indications such as rapid increase in size or progressive cardiac disability; (2) close the fistula either by direct attack upon it or by quadruple ligation and, if possible, resection; (3) avoid proximal arterial ligation alone*; (4) do not preserve the artery at the expense of the vein; (5) provide adequate exposure and control the vessels which are being dealt with.

Arterial Aneurysm

Before any intervention is undertaken every aneurysm requires close observation and study. The condition, when non-traumatic, is often associated with general arterial degeneration and not infrequently more than one aneurysm is present. For instance, a peripheral aneurysm may be the cause of the obvious symptoms and signs, but a co-existent aortic aneurysm may be the greater menace to life. The general condition, especially with regard to syphilis, the state of the vessels and of the circulation in the affected part, may all have an important bearing on the management. Sudden changes often mean thrombosis in the sac and may herald gangrene. In peripheral aneurysm leakage is more likely than sudden rupture. Aneurysms of the limbs, near the trunk, or in the chest or abdominal cavities, each demand different types of intervention. In many cases operation is associated with great risk, but aneurysm is a serious and progressive disease which is fatal sooner or later.

The methods of treatment available are mainly: excision, ligation or some type of endo-aneurysmorrhaphy in which the aim is to reconstruct the affected artery or to obliterate the sac without the risks associated with excision. *Excision* has been very successful in dealing with peripheral aneurysms and is the operation most generally employed in Britain. It has also been employed for iliac, axillary, subclavian and carotid aneurysm with complete success. For aneurysms of the smaller accessible vessels it is always the method of choice. It is true that there is some risk of gangrene, and that patients sometimes complain of slight weakness of the limb after interruption of the main blood supply; it is to diminish these risks that some surgeons feel it a duty to attempt reconstructive operations or to employ sympathectomy either as a preliminary intervention, or at the time of the ligation, or as a post-operative measure.

Ligation is one of the oldest methods and still commands a place in modern practice. The ligature may either be applied just above the aneurysm, as was advocated by Anel in 1710, or at a distance on the proximal side as introduced by John Hunter in 1785. (Fig. 244.) Three advantages are claimed for the latter method: the vessel can be approached where it is not distorted by the sac, is more likely to be healthy, and there is an intervening set of collateral branches, the presence of which will ensure that the circulation through the sac is

* [illegible]
but
Tha
the

slowed and diminished though not immediately arrested. As a result, the clot which forms is firmer, laminated and more likely to become safely consolidated. Ligation of the femoral artery in Hunter's canal for popliteal aneurysm has proved most successful. For the inexperienced surgeon ligation will certainly be safer than excision. In certain situations, and notably for aneurysm of the innominate and the carotid in the neck, immediate proximal ligation (Anel) is indicated where practicable. In these cases it may be wise to combine this with distal ligation to guard against recurrence of pulsation by means of collateral channels. Distal ligation alone has been employed when an approach to the proximal artery has not been possible. The idea is to diminish or discourage the flow through the sac but there is the risk that there may be consequent abnormal dilatation on the cardiac side from the dammed-up circulation.

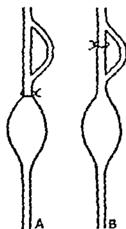


Fig. 244.—Proximal ligation.
A Immediate (*Anel*)
B Intermediate (*Hunter*)

Endo-aneurysmorrhaphy, devised by Matas of New Orleans in 1888, consists essentially of a direct intra-saccular attack with the object of either completely obliterating the aneurysm from within or obliterating the sac though leaving the vessel intact. The underlying idea is to bring about cure with the least disturbance of the collateral circulation and of the parts about the sac. The method is technically more difficult than excision. It has been extensively practised in America with much success. Writing in 1939, Homans of Boston, one of the most reliable of surgeons, stated "For aneurysms of the great vessels, the obliterative aneurysmorrhaphy of Matas is most likely to succeed and produce a permanent cure." Endo-aneurysmorrhaphy has been applied successfully to large mycotic aneurysms in cases of infective endocarditis now curable because of antibiotics and in the case of a popliteal aneurysm.*

Compression of the main supplying vessel has been entirely superseded as a sole treatment, but may be a valuable adjunct when there is recurrent pulsation after ligation. It is also a method of encouraging the development of the collateral circulation before surgical intervention; for example, in the case of proposed carotid ligation

The choice of method.—*Excision* provides permanent cure for, once satisfactorily concluded, there can be no recurrence of the aneurysm at the same site It may be a difficult operation fraught with risk to surrounding parts Before it can be undertaken the circulation through the sac must be under complete control In some situations the exposure may present anatomical difficulties but the surgeon must remember that it is not essential to be hidebound by the traditional approach to great vessels. In practice the operation has been very

* Lambert Rogers, *Brit J Surg*, 1951, xxxix, 35

satisfactory and there has been no greater risk of gangrene than with ligation. *Ligation* does not provide security from recurrence and the sac is exposed to secondary changes which may be serious. As a rule, the operation is very simple and can often be carried out under local anaesthesia. If it fails the sac can be excised as a secondary intervention or it can be dealt with by incision, turning out the contents and packing. *Aneurysmorrhaphy* has the advantage that only one face of the sac need be exposed and that the operation can be completed without disturbance of the surrounding parts.

Technique.—Before interfering with the circulation of a limb by operation the collateral circulation should be investigated by certain tests. The collateral circulation is efficient if (i) the peripheral pulse distal to the aneurysm is absent but the limb is of good colour and nutrition; (ii) if, when the vessel is compressed just above the aneurysm, (*a*) the good colour is maintained, or (*b*) the oscillometer reveals pulsation of any degree.

W. Scott Lang in 1887 described a simple flushing test which depended on the appearance of the rosy blush which immediately follows the removal of a tourniquet from the exsanguinated limb in the presence of a sufficient circulation (Hogarth Pringle). Matas, in 1907, suggested a further method, applicable to lesions of the limb. The limb below the lesion—a popliteal aneurysm, for example—is rendered bloodless by the application of a Martin's bandage from the toes up to the sac. A specially-devised tourniquet that compresses the artery alone is then applied just above the sac, and care taken to arrest the pulsation entirely. The devascularizing bandage is allowed to remain for five to ten minutes according to the age of the patient—the older the patient the shorter the period; it is then removed, leaving the artery occluded. If the anastomotic circulation is satisfactory a blush rapidly descends almost to the toes, but not infrequently is arrested, for a short time, a few inches below the point at which the artery is occluded. By degrees, however, the evidence of returning peripheral circulation may be observed until the extremity of the limb is reached, though it may take several minutes.

The particular operation must naturally depend upon the situation of the aneurysm, its size and form, and also upon the nature of the sac wall, and the efficiency of the collateral circulation. The ideal operative intervention would aim to preserve the circulation through the affected artery by Matas's restorative or reconstructive endo-aneurysmorrhaphy.

Preparation for operation.—For all disabling aneurysms, and in elderly people, a period of rest in bed is essential. It is sometimes expedient to adopt measures to encourage the *peripheral* circulation. Intermittent occlusion of the artery involved either manually or by selective tourniquet pressure and sympathectomy are the principal methods available. The general nutrition of the patient also demands attention. The skin of the whole limb should be prepared. Usually

there is no contra-indication to general anæsthesia but spinal anæsthesia may suffice. Local anæsthesia should not be used, except for very small and easily exposed aneurysms. The control of the circulation is most important but the main considerations have already been set out (*see* pp. 545 *et seq.*). Whether for ligation or for local intervention, the position of the limb should be carefully considered, for the surgeon must not be hampered in any way. For popliteal and calf aneurysms the patient should be turned face downwards, and for those about the root of the neck the shoulders should be well elevated and the arm pulled firmly down by the side. For axillary aneurysm the body should be almost over the edge of the table or the patient should lie on the opposite side with the arm of the affected side suspended from a mast. When excision is to be undertaken incisions must be ample; unimpeded exposure is often the key to success.

Excision of the sac.—The sac is treated like a non-malignant tumour and excised from its surroundings. Ample exposure is essential, and the whole extent of the sac must be defined so that the main vessels can be readily seen. The sac may be separated by gauze stripping, or by the finger, though knife or scissors may be necessary. Special care must be taken to avoid injury to nerves and other important structures that may be adherent. Arterial branches are carefully ligated outside the sac as they are exposed. If possible, the sac should be excised without opening, but this may be out of the question because of its bulk or fragility. Sometimes the operation is facilitated by opening, clearing and packing the sac with gauze. Parts of its wall may even have to be left adherent to important structures. During the dissection the surgeon will have a good opportunity to tie the main artery at its entrance to and exit from the sac.

After removal of the sac care must be taken to tie all vessels, arterial and venous, and a close search must be made for open mouths or retracted vessel ends. The vessel clamp or tourniquet should then be cautiously released so that hidden or unexpected bleeding-points may be revealed.

The associated vein may be readily identified, or it may be spread out like a ribbon, in which case it is more easily exposed near the origin of the sac. It must be caught and tied before being divided

Excision of the sac usually produces cure, but the operation may present difficulties, some of which may be overcome by the intra-saccular method The surgeon may have to be content with partial excision

The danger of gangrene must never be forgotten, and the closest attention should be given to the circulation throughout the limb. The collateral circulation should be investigated before or during the operation, and the age and general condition of the patient taken into consideration When the collateral circulation is doubtful or manifestly inefficient, the blood supply may be preserved by either a venous graft, or an arterial graft (p 558).

Ligation.—The main points about proximal ligation (Hunterian) have already been dealt with (pp. 562 *et seq.*). If it is decided to apply the ligature immediately on the proximal side (Anel) the surgeon must remember that the vessel may be displaced from its accustomed position by the aneurysm, which is often friable, and the greatest care must be taken not to rupture its wall in the attempt to expose the main vessel. An operation commenced with the intention of applying a proximal ligature very often ends as an excision, and probably with the best possible result. After immediate proximal ligation, pulsation in the sac, though greatly diminished, may only slowly disappear and the aneurysm may become more prominent for a time. Complete failure to cure or recurrence is not unknown. When the aneurysm is so situated that excision is feasible, this can sometimes be performed as a secondary intervention.

It may be said that it was failure to obtain a permanent cure of the aneurysm by double ligation that led to complete excision of the sac, and to aneurysmorrhaphy when because of its close adherence to its surroundings this was not possible. (Matas, 1888, in the case of an axillary aneurysm which had been ligated above and below but which recurred and was densely adherent to the brachial plexus.) The fact remains that many cases are cured by the simple proximal ligation after the Hunterian plan. This is the simplest method and should be used in all elderly or debilitated subjects. In popliteal aneurysms it is eminently successful and in intra-cranial aneurysms in the carotid territory, division of the common carotid between ligatures applies the Hunterian principle and yields excellent results.

Aneurysmorrhaphy.—There are three methods: the obliterative, the restorative and the reconstructive.

(1) *Obliterative endo-aneurysmorrhaphy.*—This method is used in place of excision in order to interfere as little as possible with the surrounding structures, and thus to preserve the collateral circulation. It consists in laying open the sac by a free longitudinal incision after the temporary but secure and complete arrest of the circulation on both the proximal and distal sides. The clot is then removed and the interior dried. The main step is the occlusion by suture of the orifices of vessels communicating with the sac and its obliteration by superimposed tiers of suture

In obliterating the orifices of the small communicating vessels, sutures of silk or chromic catgut, on a curved needle without cutting edges, are employed. The sac is closed by suture, commencing at the deeper portion, which brings together the lateral walls in the middle line. (Fig. 245A.) Several tiers of continuous or interrupted sutures are thus applied until the main arterial orifices and entire sac are obliterated

(2) *Restorative endo-aneurysmorrhaphy.*—This operation is only applicable to sacculated aneurysms where the communication between

the sac and the main vessel is small and well defined, and the arterial wall is comparatively sound.

Complete hæmostasis is secured by a reliable tourniquet. The sac is freely opened, all loose clots are removed, and the communication leading to the main trunk is closed by a continuous suture of fine chromic catgut or silk, passed through all coats of the vessel wall. (Fig. 245B.) The remainder of the sac is then obliterated by bringing its surfaces together, as in the obliterative method.

Where the opening of communication between the aneurysmal sac and the artery is large, the greater part of the sac may be cut away,

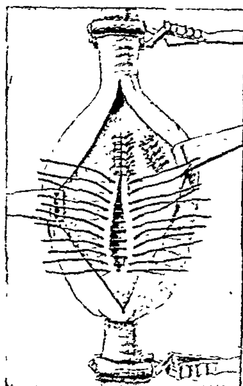


Fig. 245A.—Obliterative endo-aneurysmorrhaphy.

The orifices in the aneurysmal sac are obliterated by sutures, commencing with purse-string sutures at each orifice followed by separate sutures. The walls of the sac are now to be brought together by several tiers of sutures.

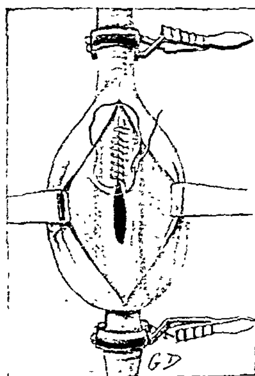


Fig. 245B.—Restorative endo-aneurysmorrhaphy.

Case of sacculated aneurysm showing the single orifice of communication being closed by a continuous suture without obliterating main trunk—a rare procedure.

NOTE.—These illustrations are of necessity diagrammatic. Rubber slings to control the vessels are better than clamps.

leaving just enough of its base to close in the vessel, the object being to preserve its lumen as far as possible. There is, however, considerable risk of clotting at the line of suture, and the thrombus may extend into the trunk of the artery.

(3) *Reconstructive endo-aneurysmorrhaphy.*—Though theoretically ideal, this operation can rarely be carried out, and is practically limited to fusiform aneurysms with firm and elastic walls, in which the two openings of the main channel lie close to one another, on the same level, and with an easily accessible sac.

The sac is laid open as before, and a soft, sterile greased india-rubber catheter passed upwards and downwards into the lumen of the vessel, and over this a new channel is reconstructed from the sac walls. The first layer of sutures should be interrupted, the catheter being removed before tying the last suture. The remainder of the sac is then obliterated by rows of sutures, as already described. In this, as in the previous operation, heparin will help to diminish the risk of intra-vascular clotting.

In all these operations there is usually free oozing from the suture-line as soon as the tourniquet is released, but it almost invariably ceases spontaneously in a few moments. If necessary an additional suture must be introduced here and there at oozing points.

After-care.—Dressings should be very lightly applied and there must be no constriction lest the developing circulation is impeded. The limb should be slightly flexed and laid comfortably on a soft pillow or a water cushion. The position should be changed from time to time in order to vary the pressure of its own weight. It should be kept cool by being exposed to an electric fan while the patient's body should be kept hot to relax the peripheral vessels. The returning circulation soon becomes evident and all danger of gangrene should be passed by the end of a week. If the skin is a good colour and the parts are warm, the absence of a palpable peripheral pulse is of no moment.

Results.—In the absence of complications at the time of operation, the immediate results are good. Gangrene and secondary hæmorrhage are the greatest risks Matas* quotes an overall mortality of 4·5 per cent. In 3·5 per cent. of the cases some degree of gangrene developed and in 1·6 per cent. secondary hæmorrhage. Relapse of the aneurysm occurred in only 1 per cent. As in other conditions where there is general arterial degeneration, some late deaths from embolism, coronary thrombosis and cerebral hæmorrhage must be expected.

Aortic Aneurysm

Thoracic and abdominal.—G. H. Colt, by careful investigation into the natural history of this condition, has been able to show that in spite of proper medical management the average duration of life is only about 18 months.† The cases reviewed were drawn from the labouring populace, but even among more sheltered lives expectation of life is probably not more than three years. Such figures supply some justification for the attempts which have been tentatively made over a number of years to treat these cases by the introduction of wire into the sac in the hope of bringing about cure by clotting and consolidation. The risk of embolism has often been urged against this method, but Colt's close scrutiny of all the published cases does not support this fear. Wiring for aneurysm was introduced by Moore and Corradi (1864–79) but it is only since Colt invented an ingenious apparatus for

* *Annals of Surgery*, November, 1940, cxu, 895.
† *Quarterly Journal of Medicine*, April, 1927, xx, 331.

the precise introduction of the wire that the plan has become practicable.* By means of this apparatus several feet of wire can be delivered into the sac in such a way that it opens up like an umbrella. A trial of this method seems justified in cases of uncomplicated aneurysm when adequate medical management over a period of two months has failed to relieve the symptoms, especially pain and obvious increase in size and when the case is unsuitable for resection with or without grafting. Blakemore† has accurately modified the procedure by means of electrothermic coagulation The wire is heated electrically and near the sac walls where the blood stream is slowest coagulation occurs. Near the centre of the aneurysm the blood flow is too rapid to be heated sufficiently to coagulate.

Results have been encouraging and in many cases life has been prolonged and made more bearable.‡ In abdominal cases some striking cures have been recorded, patients surviving in good health for 17½, 10½ and 6 years. The primary mortality has naturally been high, and many late deaths have occurred from rupture of the aneurysm and from recurrence, but in any event the disease is desperate and distressing and for the most part the treatment has only been carried out late in the disease. Colt asserts that " the best chance to cure by wiring is when the patient is in good general health and the aneurysm and the interior of the sac smooth and regular ".

Successes have recently been obtained from excision or resection and grafting of certain of these aneurysms and wiring operations will in future be reserved for cases in which more radical surgery is inadvisable.

Preparation.—A preliminary period of rest in bed is essential. The diet should be liberal with plenty of milk to supply the calcium.

Technique.—The special instrument consists of trocar, cannula, container for the wire wisp and ramrod. (Fig. 246.) The steel wire wisps are made in two sizes yielding different surface areas. The surgeon must familiarize himself thoroughly with the apparatus before essaying the operation and take the greatest care to guard against infection In thoracic cases the skin is incised to diminish the risk of carrying infection into the sac. In most cases there was either an external swelling or evidence that the sac had reached the parietes in front or behind The aneurysm has been exposed and treated after thoracotomy (Finch). In abdominal aneurysms the abdomen should be opened at a convenient spot nearest the maximum prominence of the tumour. Adherent viscera should be separated, or omenta with big vessels turned aside, so that the trochar may be inserted without risk of injury to these structures The trochar is not plunged into the aneurysm but is steadily pushed through its wall. If firm clot is encountered, the direction of the instrument should be altered so as to pass into the interior of the sac where the blood

* *Lancet*, 1903, ii, 808
† *Ann Surg*, 1947, cxxvi, 195
‡ Colt, *Med Press and Circ*, May 26, 1937, cxciv, 499.

is freely circulating. This is tested by removing the trochar, when the blood should spurt from the cannula; the wire must never be introduced unless this occurs. The cartridge containing the wire is fitted to the cannula and the ramrod is used to push its contained wisp

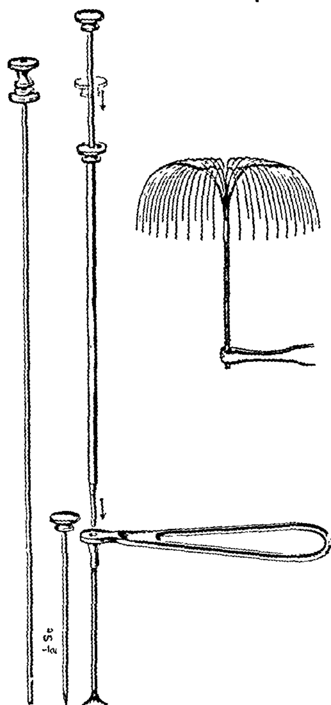


Fig. 246.—G. H. Colt's apparatus for wiring aneurysm.

through the cannula into the sac, where it expands. This step also must be done slowly and deliberately. When the wisp is safely de

ar

precaution of surrounding the site of the proposed puncture with a loose purse-string suture which is tied after removal of the instrument. If oozing persists when the precautionary purse string has not been applied, one or two interrupted sutures of fine catgut or silk in the adventitia will draw the parts together and arrest the flow. The disposition of the wire and subsequent change in the size of the aneurysm can be determined by X-ray examination. When pulsation has not ceased or pain is unrelieved, the operation may sometimes be repeated with success. Wisdom dictates a period of rest after the operation with a generous diet and plenty of milk, and, if indicated, anti-syphilitic remedies.

Complications.—Contrary to expectation, subsequent leaking at the site of the puncture has not been a cause of anxiety. In the abdominal cases acute dilatation of the stomach about the ninth day has been rather frequent. If anticipated, promptly diagnosed and treated by immediate use of the stomach tube, it ought not to be fatal.

Another method of relief for thoracic aneurysm is **sternal decompression.** The sternum is divided or split from the notch well into the body and the halves are forced aside by a bone wedge. Patients are said to have obtained comparatively long periods of relief as the result of this intervention.

In the last four years there has been a revival of interest in the treatment of aneurysm of the abdominal aorta by ligation or aneurysmorrhaphy. Those interested should read the fascinating papers by Elkin, Bigger and Matas.*

Ligation of abdominal aorta.—Aneurysms below the origin of the renal and inferior mesenteric arteries may be treated by ligation of the aorta proximal to the sac. At least six successful cases had been recorded by 1940 and further successes have been reported since, including resection of the aortic bifurcation.† By 1948 twelve successful aortic ligations were on record and others have been added since. After opening the abdomen the great vessel is exposed through the posterior peritoneum, carefully freed from its surrounding at the proposed site of ligation and secured with ¼ in. tape.

Rupture or suppuration of a peripheral aneurysm, or impending gangrene, usually demand amputation of the limb, but it may be worth while to try simultaneous ligation of the artery and vein with incision of the sac Bleeding from the sac may be treated, after ligation of the artery, by laying it freely open and packing the cavity or by performing aneurysmorrhaphy after controlling the artery

Cirsoid aneurysm.—This condition is best treated by complete excision whenever its situation allows If possible, the incisions should be made half an inch from the edge of the aneurysm so that the supplying vessels can be caught where their trunks are well defined. Where this method is impracticable, the supplying vessels should be tied. It is not always possible, however, to identify the individual vessels ‡

* *Annals of Surgery* for November, 1940, cxii, No 5, 895
† *Ann Surg.*, 1948, cxxvii, 1
‡ Lambert Rogers, *Brit J. Surg*, 1955 (in press)

In some parts, like the scalp for instance, interlocking sutures of silk or silk-worm gut or nylon may be placed around the periphery of the lesion. The whole thickness of the scalp is then incised and bleeding arrested by placing artery forceps on the cut edges of the galea. The lesion is then dissected away from the deep aspect of the skin, some of which may require to be removed.*

After removal of the affected parts any vessels which have been caught by clips should be tied. The interlocking stitches are then removed one at a time and any fresh bleeding dealt with. Seeping hæmorrhage from the cut edge of the scalp may be further controlled by a continuous running stitch of catgut along the edge. This secures hæmostasis and does not interfere with approximation of edges and ordinary closure of the wound. The continuous stitch may be left *in situ* or it may be cut here and there after the edges of the wound have been carefully approximated.

PERIARTERIAL SYMPATHECTOMY

This operation, in favour for a few years largely owing to Lériche and the French school, is rarely if ever performed to-day. Its effects are transient and less apparent than those following sympathetic ganglionectomy or ramisection

The adventitia is removed from the whole of the circumference of the artery. Painting the artery thus exposed with 10 per cent. phenol will ensure that all periarterial nerve fibres are destroyed. If it is difficult to carry out this stripping, or as an alternative, the adventitia may be injected with absolute alcohol as advised by Sampson Handley. To make this effective not less than an inch must be injected, and it must be all round the vessel as in the stripping operation.

BLOOD TRANSFUSION

During recent years great advances have been made in the theories underlying the practice of blood grouping and matching, whilst considerable knowledge has accrued on the question of blood substitutes, and on the separation and properties of the proteins of blood plasma. The unprecedented use of blood and blood substitutes during the 1939–45 war has provided a vast amount of clinical material of which many transfusion officers of distinction have taken full advantage, and have contributed greatly to the subject. It is not possible to discuss the whole matter fully in this section, but readers particularly interested should refer to a review by Drummond.†

It will be seen from the brief, simplified and admittedly incomplete remarks, which are to follow, that the question of determination of blood compatibility has passed from the realm of the clinician to that of the clinical pathologist.

* Lambert Rogers, *Aus N Z J Surg*, 1936, vi, 99
† *Post-Grad Med J*, 1950, xxv, 420, 471

Blood Grouping

In 1901 Landsteiner* found that the red cells of human blood might contain either of two agglutinogens which he called A and B, or they might contain both A and B, or neither. He also demonstrated in human serum anti-A and anti-B agglutinins which might be present separately or together, or absent, and he also showed that the interaction between an agglutinogen in the cells and a complementary agglutinin in the serum led to a clumping of the red cells and consequent incompatibility. Clearly, no blood can have agglutinogen and *its complementary agglutinin in its cells and serum. Moss (1910)*† called the blood groups 1, 2, 3 and 4, but more recently it has been recommended by the League of Nations that the ABO classification, as being more descriptive and less liable to misinterpretation, be adopted (Table I).

Table I

ABO or International	Agglutinogen in Red Cells	Agglutinins in Serum	Moss
AB	A & B	None	1
A	A	Anti B	2
B	B	Anti A	3
O	None	Anti A & B	4

International O (or Moss 4) has been called the " universal donor " group, but this term should be abandoned as no count is taken of the many known sub-groups and the Rh factor, and the description " universal " may, therefore, be misleading. Unless trained staff are available for matching it is probably safer to use small pool plasma, serum or blood substitutes

A blood substitute, to be effective, must have an osmotic pressure equal to that of blood and 50 per cent. of the volume infused must remain in the circulation for at least 24 hours. It must of course be *harmless to the recipient. Such a substance is as effective as plasma* and its infusion will result in a sustained rise in blood pressure in conditions of shock. Dextran fulfils these criteria, and is very effective in practice. Polyvinylpyrrolidine has been used in Germany and is available in this country under the name of " *Plasmosan* " but it probably does not remain within the circulation more than a few hours, and is not so effective as is Dextran. Dextran in conditions of traumatic shock should be given as rapidly as possible until the blood pressure of the recipient is raised to a proper level, and there can be no reason for a drip transfusion in such cases. Before blood substitutes are used, serum must be obtained from the patient for cross-matching

* *Wien. Klin Wschr.*, xiv, 1132

† *Johns Hopk Hosp. Bull*, xxi, 63.

purposes, as there is a distinct tendency for serum obtained subsequently to infusion with blood substitutes to give rise to difficulty in interpreting results owing to intense rouleaux formation.

The Rhesus Factor

The Rh factor becomes of increasing complexity, and the really important practical points about this for the clinician to remember are listed below.

(1) If a patient has a history of previous transfusions, he or she should be Rh typed, or alternatively given Rh negative blood.

(2) All girls and women in the child-bearing period of life should invariably be given blood of a similar Rh group. A transfusion of positive blood, when the recipient is a young girl who is negative, may sensitize her with respect to a subsequent pregnancy, and it may be that she will never give birth to a live infant.

(3) Urgent transfusions in obstetrical departments must always be of Rh negative blood.

(4) Erythroblastotic infants must be given Rh negative blood.

(5) As only 15 per cent. of Europeans are Rh negative, this blood is not so readily available, and with the exceptions given above all intending recipients should be Rh typed and given blood homologous in this system, as well as of course in the ABO system.

It will be appreciated from the very brief and incomplete survey of the problems that blood grouping is a matter of great complexity and that only those with special training in the subject should undertake cross-matching. It should be noted, especially by the impatient surgeon, that the minimum time taken to effect a reasonably safe cross-match is some hours, and if the emergency is so great that it will not allow for this interval, plasma, blood substitute or blood compatible in the ABO main groups will have to be used, the risks being appreciated and accepted. In obstetric crises plasma should be used if Rh negative blood is not available.

Indications for Blood Transfusion

Transfusion of blood, or its derivatives, is a form of replacement therapy and should always be done for a definite and precise object, and should not be performed as a sort of vague "tonic". The ready availability of blood and the ease with which transfusion can be carried out has often resulted in its rather indiscriminate use, and, in spite of our increasing knowledge of blood groups, and in spite of the very careful and accurate methods of cross-matching, there is still an appreciable morbidity and even a mortality subsequent to transfusion which is approximately equivalent to the mortality of uncomplicated appendicectomy and is about 0·2 per cent.

It is difficult to give precise indications for transfusion of blood or its derivatives, but broadly speaking it may properly be used in the following circumstances.

(1) To replace and compensate for sudden diminution of circulating volume in the following instances: (*a*) acute hæmorrhage; (*b*) shock, traumatic and surgical, which does not readily respond to other measures; (*c*) acute intestinal obstruction; (*d*) acute peritonitis; (*e*) burns; (*f*) crush syndrome; (*g*) some cases of acute pulmonary œdema associated with diminished blood volume.

(2) In chronic anæmias when specific remedies are either not available, or when if available their effect cannot be brought about in time for a special circumstance—such as an operation. In this type of case it is wise to use fresh blood or packed cells, and in the former quite small quantities will sometimes suffice, as it appears that the blood forming tissues of the body are stimulated thereby. In this connexion small transfusions are often of great value to promote healing and repair when these processes are sluggish.

(3) In hæmophilia and other hæmorrhagic diseases, in certain cases of prothrombin deficiency and sometimes in fibrinogen deficiency.

(4) In some cases of hypoproteinæmia.

(5) In certain cases of neonatal hæmolytic disease.

With regard to acute hæmorrhage when compensation begins to fail there is a fall of blood pressure which is commensurate with the amount of blood lost. However, an initial vasovagal syncope may cause a sudden fall of pressure early on, but there is generally recovery from this. If 30 per cent. of the blood volume is lost the pressure is usually below 95 mm. Hg and if 40 per cent. is lost the pressure is about 80 mm. Hg (Robertson and Bock).* The pulse rate is not always a reliable guide to the degree of hæmorrhage. If there is a blood loss of 500–750 ml. there will be no significant symptoms except possibly a vasovagal syncope, but if the loss is of 750–1,250 ml. there will be moderate shock and transfusion is indicated. If the loss of blood is more than 1,750 ml. shock is likely to be profound and usually fatal unless immediate transfusion is carried out. There has recently been a change in opinion about the quantity of blood to be given in acute blood loss, and transfusions tend to be more massive There is, however, no necessity to replace all the blood lost, but sufficient should be given to allow and stimulate the compensating processes of the patient to become effective. Transfusion will rarely be indicated unless more than 1 litre of blood has been lost, and therefore this quantity should be the minimum to be transfused The blood pressure is raised 10–20 mm. Hg following the administration of 500 ml. of blood (Kekwick *et al* †), and this amount or more should be given rapidly by means of a pump if necessary until the blood pressure reaches 120 mm. Hg after which the transfusion can be stopped. If there is a fear of repeated hæmorrhage, it is wise to give blood over and above the amount necessary for recovery in order that there will be some reserve. In acute blood loss it is difficult to give too much blood and overload the heart, the danger being that too little is given, and in

* *M R.C Spec. Rep. and Ser* No 25, p 213
† *Lancet*, 1941, i, 99

the cataclysmic hæmorrhages it may be necessary to have more than one apparatus working, through different routes, in order to secure a really rapid transfusion or the blood may be given by the intra-arterial route. (*See* below.) When whole blood is not available in sufficient quantity, plasma or Dextran are almost equally effective. The dangers accompanying severe blood loss from gastro-duodenal hæmorrhage far outweigh any hypothetical risk of restarting a hæmorrhage from an ulcer, but by general concensus of opinion the drip method should be used, except possibly in those cases where the blood loss has been extreme and when the patient is being prepared for operation.

Intra-arterial Blood Transfusion

It has recently been suggested that intra-arterial blood transfusion has many possible advantages. In conditions of acute blood loss with severe peripheral anæmia, blood given intravenously may merely stagnate in the dilated peripheral vascular bed, but blood given intra-arterially may restore the circulation sufficiently to reverse the "shock" process. It has been suggested that the blood be given directly into the aorta* or more often into the radial artery,†‡ the blood being injected under pressure and of course directed centrally. The method is not without risk, various degrees of gangrene, and even loss of limb having occurred following the procedure, and it is doubtful whether the physiological concepts of the advantages of the method can be in fact substantiated.§ Any possible advantages may be outweighed by the risks associated therewith.

In the case of burns, the fluid lost, which is essentially plasma, can be reckoned from the area burned. Taking the palm of the hand as representing 1 per cent. of the body surface, a rough estimate can readily be made of this area. If this is more than 10 per cent. a transfusion of plasma should be given whether shock is clinically evident or not, the amount being approximately 100 ml. for every 1 per cent. of surface burned. An average severe case requires about 1 litre immediately and later a further 2–3 litres, but in some cases as much as 15 litres may be required, and this quantity should be given over the first 48 hours following the burn, the first 500–1,000 ml. being given very rapidly if shock is manifest The cervical veins should be watched for circulatory overloading (Black,‖ Harkins *et al.*¶).

In intestinal obstruction plasma should be used unless there is strangulation, when whole blood is the medium of choice, and the quantity may have to be rather large and should be governed by the state of the patient and by the hæmoglobin and hæmatocrit readings. In acute peritonitis 1 litre of plasma may be a life-saving measure.

Where blood transfusion is indicated in the chronic anæmias the use

* Haxton, H A, 1952, *Manchr med Sch. Gaz*, xxxi, 21.
† Horton, J A G, Inkster, J S, Mackenzie, A, and Pask, E. A, 1953, *Brit. Med J*, ii, 1294
‡ Bingham, D L C, 1952, *Lancet*, ii, 157.
§ Maloney, J V, Smythe, C McC, Gilmour, J P., and Handford, S W, *Surg Gynæ Obst*, 1953, xcvii, 529
‖ *Brit Med J.*, 1940, ii, 693
¶ *J. Amer. Med Assoc*, 1945, cxxviii, 475

of packed cells is preferable to that of whole blood, and no more than 1 litre should be given by the drip method at any one time, in order to avoid overloading of the circulation.

Whole Blood Storage

Since the advent of modern methods of blood storage, direct methods of transfusion have fallen into disuse, except possibly in hæmophilia. Storage with sodium citrate solution has given place to storage with di-sodium citrate dextrose (ACD) solution and in this medium it has been established by differential agglutination methods and by the tagging of red cells by radio-active isotopes that red cells stored for 16–18 days are little, if at all, inferior to fresh red cells, and that transfused red cells survive in the recipient's circulation for 100–120 days, which is presumably the normal life of such cells.

Blood Plasma

The availability of plasma, dried or citrated, and the fact that there is no question of incompatibility have resulted in plasma being a great boon, and its use has been responsible for the saving of thousands of lives. Dried plasma lasts apparently indefinitely and can be transported easily. Plasma used to be made from pools contributed to by a large number of donors, and if one of the donors happened to be infected with an icterogenic virus, the whole pool was contaminated and any recipient was liable to become infected and develop jaundice. Homologous serum jaundice has an incubation period of 40–120 days and the association of an attack of jaundice with a previous transfusion of plasma was not always appreciated. Its incidence is variously reported and is sometimes as high as 10 per cent. More recently dried plasma has been manufactured from small pools when its incidence is reduced to about 1·5 per cent., but homologous serum jaundice also occurs after transfusion of whole blood in about 1 per cent. of cases. The disease may have serious consequences and may even be fatal in something over 1 per cent., and some observers quote a very much higher mortality. However, in spite of this risk, plasma is an invaluable blood substitute on occasions, and it has its particular indications.

Complications

Apart from the transmission of jaundice, the following complications may result from transfusion.

(1) **Hæmolytic reactions.**—These are usually, but not always, a result of incompatibility, but may result from the use of blood already hæmolysed The clinical picture may be divided into three phases: the first occurring during transfusion and being accompanied by headaches, breathlessness, a constant lumbar ache with flushing, tachycardia and a rigor followed by circulatory failure. The second phase is that of recovery from shock with hæmoglobinuria, gradually merging into the third phase of anuria and uræmia at the end

of a week or so. Treatment consists of stopping the transfusion immediately in the first phase, encouraging diuresis and alkalinizing the urine in the second phase, and in the third phase, giving a spinal anæsthetic, a splanchnic nerve block and possibly decapsulating the kidneys.

(2) **Febrile reactions.**—These may occur due to pyrogens in the transfusion apparatus and other causes.

(3) **Overtransfusion.**—This may overload the right heart.

(4) **Allergic and anaphylactic reactions.**—These reactions may sometimes occur if the donor is in a sensitive state, but they are of little importance to the recipient, and their effects soon wear off.

(5) **Transmission of disease.**—Malaria, syphilis and infective hepatitis may be transmitted from transfusions.

It is essential that when any transfusion reaction or complication occurs the drip is stopped immediately. The occurrence should be reported to the transfusion officer and the complete apparatus, with tubing and needle, preserved for his examination and investigation. In such a way further advances in knowledge will be made.

TECHNIQUE

The gravity method of transfusion is now used almost exclusively in Great Britain. The apparatus devised by the Medical Research Council and provided by the National Transfusion Service is reliable,



Fig 247.—Blood transfusion apparatus. Left, bottle of blood with sample for cross-matching purposes; and packing tin containing (right) cellophane wrapped rubber tubing, drip and needle; bottle of electrolyte solution.

convenient, efficient, simple and readily available (Fig. 247). The needle should always be inserted into the most distal vein, at least in adults, in order that more proximal veins are available for future use if necessary. When the veins about the radial aspect of the lower

forearm are used, there is more comfort and freedom for the recipient. It is often a good idea to use about 3–4 in. of polythene tubing in the vein (Fig. 248), and this can sometimes be introduced into the vein by threading it through the lumen of a French's needle (Fig. 248) previously inserted into the vein, the needle subsequently being withdrawn leaving the tubing within the lumen *in situ*. If this method cannot be used because the recipient's vein is too small, then the tubing will have to be put in place after cutting down on the vessel. The needle of the transfusion apparatus is inserted into the polythene tubing and the flow started. This method appears to allow prolonged transfusion to be achieved with the minimum of discomfort, and the least chance of the apparatus becoming obstructed. The author has found that resident medical officers prefer this method, as they are not disturbed so often, and this appears to me to be significant. It has been suggested that, where rapid transfusion is required, intracardiac blood be given by a long length of polythene tubing inserted via an arm vein, and this method may be useful, especially where there is spasm of the superficial veins due to oligæmic shock, but generally the tubing should be kept as short as possible and the transfused blood deposited, say in the axillary vein. The possible advantages of a long polythene tubing are offset by the hydrodynamics of viscous blood when flowing through a long length of narrow tubing, and it has been shown that a length of small bore polythene tubing 3 ft. long requires a pressure of 460 mm. Hg to effect a flow of 100 ml. per minute, whereas a similar pressure will effect a flow of 400 ml. per minute through a tube 3 in. long. The same authors have also shown that the most rapid transfusion can be achieved through a French's needle, as the tapering bore does not readily induce turbulence in the flow, and that, using a pressure of 100 mm Hg, the usual height of a bottle of blood, about 800 ml. per minute can be delivered If the pressure in the system can be increased to 760 mm. Hg, 1 litre of blood per minute can be achieved. It is unwise and it carries a definite risk of air embolism to use pressure applied to the air inlet tube of the bottle, but pressure can be exerted safely, by a suitable pump situated between the reservoir and the patient, and nowadays no unit undertaking major surgery should be without such a pump The most suitable apparatus consists of a cam bearing rotary roller which forces blood through the section of the rubber tube between the reservoir and the patient, the tube being laid around the walls of a cylinder * For ordinary purposes the pump can be operated efficiently by hand, and the tubing need not be removed if a

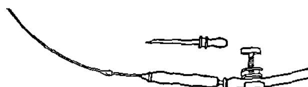


Fig. 248.—Above, a French's needle. Below, a standard transfusion needle inserted into a short length of polythene tubing, prior to insertion of the latter into a recipient vein.

* Such a pump running on ball bearings was designed and made by the late Julian Smith of Melbourne One has also been designed by the author (P M) and is made by Messrs Allen & Hanbury, London

drip rate is desired, the roller being readjusted to relieve the pressure on the tubing (Fig. 249). Where rapid transfusion is undertaken it is wise to warm the blood in a water-bath to a maximal temperature of 37° C., and this should be done immediately before use.

The importance of maintaining the strictest asepsis in establishing a transfusion cannot be emphasized too strongly. Only too often septic arms occur following the operation, and frequently these are slow in healing and give rise to prolonged and painful restrictions of movement It can only be very rarely that the necessity for blood is so urgent that full aseptic precautions cannot be taken.

Transfusion in Children

With regard to transfusion in young children, 10 ml. of blood per pound of weight (22 ml. per kilogramme) is approximately equivalent to 500 ml. of blood in the adult, and from these data, calculations as to probable amounts of blood or blood substitute can be made. On the other hand, of course, it is the clinical manifestations which determine whether transfusion shall be continued or stopped. The internal saphenous vein above the ankle joint is a useful place to insert polythene tubing, and there is little fear of it being dislodged by the child's movements. In the infant the scalp veins can be punctured percutaneously, as can also the external jugular veins. If it is decided to cut down, either the internal saphenous vein just above the ankle joint or the ante-cubital veins can be used Within 24 hours of birth, the umbilical vein is probably the most satisfactory, the cord being cut across and a cannula or preferably polythene tubing inserted into the lumen of the vein, the margins of the vessel being held by mosquito forceps. The tubing is inserted for about 2 in., at which depth it is not necessary to ligate it in place. By means of a three-way tap and a 20-ml. syringe, replacement transfusion can be performed by the substitution of 20 ml. of the infant's blood by 20 ml. of fresh Rh-negative blood (Fig. 250a). This process is repeated until 500 ml. of blood have been used up, and such an amount results in a 90 per cent exchange of the infant's blood. This is an important and life-saving measure in some cases of neonatal hæmolytic disease, but it is essential that Rh-negative blood be used Transfusion via the anterior fontanelle into the superior longitudinal sinus is not now regularly used except when no other route is available, and the very real risks of

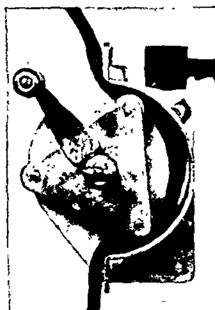


Fig. 249.—Blood transfusion pump.

osteomyelitis have caused transfusion into bone-marrow to be abandoned. In infants and small children, where a drip transfusion is indicated, it is wise to use a modified apparatus, as smaller amounts of blood have to be used, and it is important to measure these amounts more accurately than is possible with the standard M.R.C. 500-ml. bottle. A 2-c.c. glass syringe with a side inlet half-way down

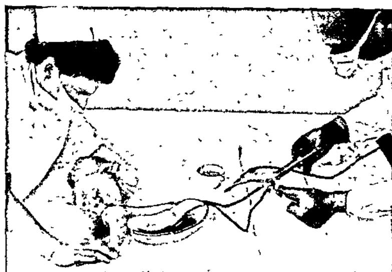


Fig. 250a.—Exchange transfusion in an infant 6 hours old. A three-way syringe is being used.

the barrel carrying a 19 SWG needle is useful for percutaneous vene-puncture in young children (Luer-Kaufman). The syringe is filled with saline solution and a scalp vein penetrated. In order to verify the position of the point of the needle a small amount of saline solution is injected. Attempts at withdrawal of blood are not successful as the

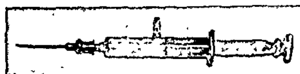


Fig. 250b.—The Luer-Kaufman syringe.

veins are so small and collapse readily. With the piston in a position distal to the side opening, the transfusion is started, the blood being pumped in by a two-way syringe between the reservoir and the Luer-Kaufman syringe (Fig. 250b).

Responsibility

Finally, it must be remembered that it is the clinician who actually carries out the transfusion who has the responsibility of checking the blood or substitute provided and of ensuring that the correct bottle

has in fact been delivered to the patient's bedside, and he must always verify this by examining the label on the bottle before starting the transfusion.

PORTO-CAVAL ANASTOMOSIS

This refers to the method which has been employed to make an anastomosis between the portal and systemic system of veins for the relief of portal hypertension.*

It has usually been employed when hepatic cirrhosis has been the main underlying factor and recurring bleeding from œsophageal varices the urgent indication. Sometimes wasting and ascites have prompted the intervention but are no longer regarded as indications. Lateral anastomosis may be made between selected veins like the portal and vena cava, the original Eck's fistula, or an end-to-end union between the proximal end of the splenic vein after splenectomy and the proximal end of the renal vein after nephrectomy, or end-to-side union without nephrectomy.

In the earlier work the union was made by direct suture and though veins are concerned the technique used in arterial suture was employed, then a method of union over a special cannula made of vitallium associated with the names of Blakemore and Lord† was popular. Most recently, however, there has been a return to hand sewn anastomoses without the use of supporting tubes.

However the actual union is made there are certain general principles that must be observed. The veins are thin walled and are easily injured and the greatest gentleness must be observed to guard against injury to the intima or the production of hæmatoma in the vein wall. Clamps used for occlusion must be delicate and light, usually of the bull-dog type and protected by rubber. The forceps for handling the open ends of the vessels must be delicate. Sutures have to be of the finest material, usually silk, not thicker than 6/0 which must be sterilized and used out of liquid paraffin. Heparinization is essential, the clotting time being prolonged by its means to about 15 minutes and this must be maintained for 24 hours after the operation, the foot of the bed being elevated to assist the blood return. The vessels employed must lie together without the least tension. When the splenic vein is used it requires to be mobilized by dividing and ligating many tributaries entering it from the pancreas; it requires about 5–6 cm. of both the splenic and the renal vein to allow of a union without tension. The veins must not be kinked, twisted or obstructed in any way. The open ends must be cleared by irrigation with isotonic sodium citrate solution and the parts kept moist by the same means throughout. During the manipulations the veins should lie on petroleum jelly gauze

These operations are tedious and exacting; there must be no attempt

* See also R Milnes Walker, *Lancet*, 1952, i, 729
† *Ann Surg*, 1945, cxxii, 476.

to hurry, the surgeon being prepared to spend three or four hours if necessary.

In the hands of skilled surgeons taking every possible care the primary mortality has been about 15–20 per cent. Results have on the whole been disappointing. (*See also* p. 904.)

VENOUS SYSTEM

For the ligation of veins fine silk is better than catgut as the walls of these vessels are thin, and catgut ligatures are apt to slip. Silk has a much better bite. This particularly applies to lateral ligatures for the occlusion of holes in big veins.

Injuries to the portal vein illustrate the problems associated with the conservative surgery of veins. This matter is dealt with in the section on the liver and its excretory apparatus at p. 906. The same problems may arise in connection with the inferior vena cava when that vessel is injured during the removal of renal or retroperitoneal tumours.

Varicose Veins

Before deciding on operative treatment it is necessary to be satisfied that the obvious varicosity is the cause of the symptoms of which the patient complains.

The reasons for the treatment of varicose veins of the leg are :—

(1) Disability arising from pain or other discomfort, especially aching and cramp on standing.
(2) Secondary changes resulting from longstanding venous congestion; such as œdema, eczema or ulceration.
(3) Hæmorrhage.
(4) Recurrent phlebitis.
(5) The exigencies of the public services.
(6) For cosmetic reasons when employment and livelihood are involved.

The mere presence or detection of varicose veins is not a sufficient reason for intervention as they are often merely an evidence of congenital tendency

Since the publication of the last edition of this book additional experience of sclerosing injections has shown their limitations and that the value of operative measures is once again becoming recognized. When the internal saphenous is varicose the vein must either be divided and ligated just below the saphenous opening (Trendelenburg operation),* or divided, the upper end ligated, and the lower part treated by retrograde injection; or the whole vein removed by open dissection, or by the extraction method of Babcock A combination of injection and operation is favoured by some surgeons but there is a swing of the pendulum away from injection treatment and towards complete surgical extirpation. Before the injection method was introduced, thorough removal of the veins usually produced cure if the operation was really indicated.

* The terminal inch of the vein is excised

When operative removal is necessary, the veins must usually be dissected out.

Incision should be directly over the course of the veins. When they are very large and adherent to the skin it is easier and better to remove a strip of skin with the vessel. If surgical removal is to be relied upon entirely the whole internal saphenous should be excised by one of the methods described below.

It may also be necessary to interrupt the blood-stream in septic phlebitis with rigors if the resources of chemotherapy have failed. For this purpose it is enough to expose, to ligate and to divide the main vein between the focus and the trunk. In both the upper and the lower limb the ligation of the vein should be carried out as far away from the septic focus as possible.

The object both of operations for the actual removal of the veins and their obliteration by injections is to divert the venous circulation from the superficial to the deep veins. It is therefore important, before undertaking treatment, to determine the condition of the latter.

Injection method.—This plan is contra-indicated (*a*) if there is thrombosis of the deep veins; (*b*) in the presence of acute phlebitis or other septic condition; (*c*) when the varicosity is due to physiological congestion, as in pregnancy; (*d*) in advanced cardiac or renal disease. Injection should only be carried out below the level of the knee and preferably in a retrograde manner. Above the knee the sclerosant may enter the deep veins by way of the communicating veins.

The solutions employed have been numerous and varied. Quinine and urethane (quinine hydrochlor. 4 gr., urethane 2 gr., and doubly distilled water, 30 c.c.) may be used. It is well to commence with ½ c.c. to determine whether or not there is a special idiosyncrasy for quinine. The usual subsequent dose is 1 to 2 c.c. Sodium morrhuate in 5 per cent. solution, mono-ethanolamine oleate, and other substances are available. It is wise to begin with a trial dose of 1 c.c., but if there is no severe reaction, doses of 3 or 4 c.c may be subsequently employed.

The interval between injections should not be less than one week. The number of injections necessary depends upon the extent and the size of the veins to be treated and the reaction of the individual. Sometimes one injection will thrombose a considerable length of the internal saphenous In an average case 4 to 6 injections will be required. The result is to thrombose the contents of the vessel. Later this thrombus becomes organized and finally leaves a hard cord which may remain permanently or may gradually disappear.

The actual injection is made with an ordinary small Record syringe with a fine, very sharp needle. The skin is sterilized with alcohol and the needle is slowly and gently thrust into the vein. It is easier to introduce the needle with the patient standing, as the veins are then prominent, but nervous subjects are better lying. The veins may then be made prominent by a loose tourniquet, which is removed

when the needle is known to be within the lumen. It is generally conceded that it is better to inject when the veins are empty.

It is absolutely essential to be certain that the lumen has been reached before the injection is made. The only way to demonstrate this is to withdraw some blood into the syringe. Once the lumen is reached the injection is slowly made but the needle is not withdrawn for a few seconds after completion. As it is withdrawn a sterile pad must be slipped over the puncture and held firmly for a minute or two. This is in order to prevent escape from the vein into the subcutaneous tissue. The puncture is then painted with iodine and the leg is supported by a crêpe bandage applied evenly from above down and worn until the next injection. The pressure of this bandage will keep the vein walls in contact for some hours. Beyond a slight burning sensation there is no discomfort and, as a rule, the patient can walk away. If uneasiness persists, rest, elevation of the limb and aspirin will bring relief. One of the great advantages of this method is that it can be ambulatory but many patients would probably do better if they spent a few days in bed after injection.

Some patients feel buzzing in the ears and have been known to taste the quinine almost at once These symptoms do not occur with oleates. Subsequently there may be stiffness and soreness for a day or two, and there is sometimes actual phlebitis with redness and swelling over the vein. As sequelæ there may be some œdema of the leg, and the thrombosed vein may remain tender. A troublesome type of thrombo-phlebitis may persist. Cellulitis and ulcer at the point of injection are both recognized as being due to escape of the solution into the tissues around the vein. They are fortunately rare and avoidable sequelæ.

Danger appears to be very remote, for many thousands of injections are made every year without untoward consequences. Pulmonary embolism has been reported but is very rare

Results.—In properly selected cases these are good provided the whole of the affected area is treated and any necessary auxiliary operation carried out Relapses from injection alone are frequent and the procedure of choice in most cases is Trendelenburg's operation combined with excision or multiple ligations, provided always, of course, that the internal saphenous system is involved and the Trendelenburg test is positive. If the small saphenous system is primarily involved the same procedure should be carried out on it.

Operation. **Removal by dissection.**—To be successful, the removal must be thorough to get permanent good results no trivial operation will suffice, and the surgeon must be prepared to do a lot of tedious dissection When the whole leg is to be dealt with the operation may take a couple of hours, or even more General or spinal anæsthesia is required. In any case the skin of the whole limb should be prepared and *the greatest care should be taken to preserve asepsis* When the veins are very dilated the leg should be elevated; an inclined plane on the

operating table is more satisfactory than suspension. If the veins are not very prominent it is a good plan to mark out their course with carbol-fuchsine before the skin is prepared and while the patient is standing. One long incision may be made over the most prominent part of the vein, extending from the saphenous opening to just about two inches above the ankle; it is much better, however, not to carry the incision behind the knee, but to make separate incisions in the thigh and leg. If it is necessary to remove the portion of vein by the knee this can be done by the subcutaneous method (*vide infra*). The skin edges should not be dissected farther back than is necessary to expose the vein completely, and in any event for not more than about an inch. If it is difficult to reach all the veins without undermining the skin, two or more separate incisions are better than flaps, as there is a risk of their sloughing. All lateral tributaries should be caught before being divided or if quite small touched with the endotherm needle carrying a coagulating current, the fat being pushed aside with the points of artery forceps. Often the veins are friable and the tributaries break off and retract. If they cannot be readily caught they may

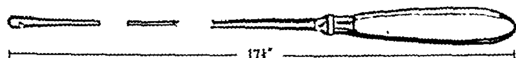


Fig. 251.—Instrument for the removal of varicose veins by the subcutaneous method. The probe is made of malleable copper. (Grey Turner's model.)

safely be left alone, for the pressure of the bandage will arrest the bleeding Trendelenburg's operation may with advantage be first performed at the upper end. All arterial bleeding must be arrested and the skin edges carefully approximated by suture. For rapid healing perfect wound suture is essential.

When the posterior or short saphenous is affected it is only necessary to remove two or three inches at the lower part of the popliteal space. Vertical incisions in this region are to be avoided when possible. A transverse incision across the lower part of the space will suffice if the edges are well retracted. The vein will be seen just underneath the popliteal fascia and can be readily removed. When there is ulceration care should be taken to diminish infection before operating, and in any event the incisions for vein removal should stop short of the edge of the ulcer by a couple of inches.

Subcutaneous removal.—This method is associated with the names of Babcock and Mayo. The idea is to remove a considerable length of vein between two short skin incisions. In the Babcock method, which is the best, the vein is enucleated by inversion, a special instrument being required. (Fig. 251.) By this means long stretches of vein—from below the knee to the middle of the thigh, or from the lower part of the thigh to the saphenous opening—can be removed. It is only necessary to make an incision an inch long exposing the vein

on the inner side a few inches below the knee. The vein is isolated and opened so that the probe can be introduced into its lumen. The probe is then pushed gently upwards as far as it will carry and another *short incision is made on to this point.* The vein containing the end of the probe is isolated, and a long silk ligature is tied tightly round the vein, biting into the notch in the probe. The vein is then ligated and divided just beyond the end of the probe. The probe is withdrawn from below carrying the inverted vein and the silk ligature with it. The isolated vein is then ligated and cut away. Sometimes it comes away very easily, but if it does not, the long silk ligature used to tie the vein to the probe is held taut from the upper incision while the vein is withdrawn with a series of jerks on the probe. Of course the lateral branches are torn across, but the bleeding is easily controlled by a firm bandage.

If the vein breaks when only a short length has been inverted the probe may be re-introduced up to the point where it broke, and here a short incision must be made so that the vein can be again tied to the probe. The method is very useful for removing the saphenous trunk. When the distance is not too great the probe may reach from just below the knee to the saphenous opening. Usually this vein has to be removed in two sections.

The method is not generally suitable for the veins below the knee, nor is it likely to be successful for very big veins or where there have been attacks of phlebitis or previous treatment by injection.

After-care.—It is wise to keep the patient in bed until the wound is healed. After extensive dissection a week or ten days or more may be necessary. For three or four weeks the limb should be supported by a crêpe bandage and kept elevated when the patient is resting.

Resection of vein at saphenous opening.—This is the **Trendelenburg operation.** The object is to ligate and divide the great saphenous at its junction with the femoral and to excise about an inch of the vein. An oblique incision is made across the upper and inner part of the thigh about an inch below and parallel with Poupart's ligament. (Fig. 252.) If there is much subcutaneous tissue it is easier to find the vein through the oblique incision, and in any case it has the advantage that a posterior branch, that would probably be missed with a vertical incision, can be found and divided. This branch, together with all other tributaries in the region, should always be sought, ligated and divided. The main trunk should be carefully exposed and sufficiently separated from its bed to allow a ligature to be passed around it. In defining the upper end care must be taken not to drag up the femoral vein. The lower end may be caught in a clamp and tied after division. The actual division should be made half an inch beyond the point at which the ligature is applied so that there can be no possible risk of the latter slipping. Some enlarged lymph nodes may be encountered about the saphenous opening, these should be disturbed as little as possible. The wound is carefully sutured, care being taken to bring the fat and deep fascia together

Resection of saphenous with retrograde injection.—This method is sometimes used when the veins below the knee have been successfully sclerosed by injection but the saphenous in the thigh remains patent and varicose. It is also an alternative to removal of the thigh veins by dissection which is, however, to be preferred. The patient should be in hospital. Local anæsthesia will suffice. The trunk of the vein is exposed just below the saphenous opening and is isolated for a couple of inches. *A ligature is applied half an inch from the femoral vein and* the trunk is clamped across about an inch lower down, the intervening portion being excised. The sclerosing solution is injected into the lower end. In this method the lower end of the vein may be of so large a lumen that it is difficult to tie it about even a large-size Record needle. A special nozzle may be used, or the vein may be ligated and the injection delivered into the distended parts below by puncture with an ordinary-size hypodermic needle or a ureteric catheter may be passed down the vein towards the knee and the injection made into it. The 5 per cent. sodium morrhuate or "Ethamolin" (mono-ethanolamine oleate) solution is used, and up to 10 c.c. may be injected. The wound should be swabbed with saline to remove traces of the sclerosing solution and should then be carefully sutured, care being taken to bring the fat together to obliterate dead spaces. The thigh is mildly compressed with bandage or strapping. The patient may get out of bed the next day but should remain under observation for two or three days. As a matter of experience it is much wiser to keep the recumbent position for a few days. There is less risk of hæmatoma and the wounds heal better. In the presence of ulceration attributed to varicosity much care should be taken in diagnosis and in preparatory treatment by rest in bed with the intelligent use of the more recent antiseptics. An attempt must be made to discover which system of veins is at fault. Sometimes removal of a section of the upper part of the posterior saphenous or even ligation and division of the popliteal vein itself leads to cure.



Fig. 252.—Incision recommended for Trendelenburg's operation.

LYMPHATIC SYSTEM : ELEPHANTIASIS

Operative treatment devised to relieve lymphatic stasis in cases of [illegible] nay be said that [illegible] Kondoleon and Sistrunk, is a surgical procedure that offers some prospect of success, especially in cases in which the lower extremities are affected. The

writers have seen great improvement after this operation but never complete cure, and relapse is not uncommon. As a rule, surgical intervention has only been carried out at a late stage and when there are secondary changes in the lymph-sodden tissues. Since the malady is progressive and invariably leads to a burdensome disability, earlier and more radical surgical treatment is justified.

Lang* made a long incision down the thigh and leg carried right to the bone. The periosteum was detached from the bone and holes were trephined through to the medulla, and into these portions of the detached periosteum were inserted. This method has been superseded by that of Kondoleon† who also used long incisions on both the outer and inner aspects of the limb and through these removed large sections of subcutaneous tissue, fat and aponeurosis, so that the muscles were left quite bare at the bottom of the large wound. The incisions were most carefully closed without drainage.

Sistrunk's operation,‡ which is very similar, begins with a long elliptical skin incision extending from the trochanter to the external malleolus. The skin is then reflected towards both back and front to the extent of an inch or two, to permit the removal of a large amount of subcutaneous fat. This fat, the skin ellipse and a corresponding strip of deep fascia is removed, the wound being sutured without drainage; a like procedure is carried out on the inner side of the leg. In each case the aim is to remove large sections of the œdematous and hypertrophied tissue and to establish free communication between the superficial and deep lymphatic systems, thereby restoring the lymph drainage. Homans (1939) asserts that lymph drainage cannot be renewed and that any benefit following operations of the Kondoleon type is derived from the removal of lymph-sodden tissues. The limited success of these operations, even when most thoroughly and carefully carried out, supports this contention. In conformity with this view, Homans advocates an operation designed to remove the greatest possible amount of the tissues between the skin and the deep fascia all around the limb. After completion, the skin, denuded of its subcutaneous tissue, lies directly on the bared muscles and bone. The operation is carried out in at least two stages and from incisions on either side of the limb. As a rule only the leg below the knee is dealt with as this is the great reservoir of fluid and where the maximum effects of its accumulation are found.

These operations are not free from risk, and unless great care is taken they may be followed by severe shock. The patient should be carefully prepared by a period of three or four weeks in bed with the limb elevated and bandaged from the toes upwards. During this period most painstaking attempts should be made to sterilize the skin and the resources of chemotherapy should be employed in every way. The actual operation should be done slowly and carefully so that all

* *Centralbl f Chir*, 1911, xxxviii, 3, 153
† *Munch. med Woch.*, 1912, ix, 1915
‡ *Collected Papers, Mayo Clin*, 1918, x, 953

vessels may be caught and tied as the operation proceeds. A tourniquet is sometimes advised, but the upper part of the thigh is often so swollen that it is difficult to compress the vessels. If the patient is not in good condition only one side of the limb should be done at a time. After operation there should be no hurry to get the patient out of bed, and a mildly elastic bandage should be worn for some months with the limb elevated. When ordinary activities are resumed bandage support, elevation of the limb when at rest, scrupulous cleanliness and the immediate care of minor infections will always be necessary.

When there is chronic ulceration or grave sepsis it may be safer to tie the external iliac artery as a first step. Great improvement often follows and, if necessary, the Kondoleon operation may be done later.

In an attempt to improve the results of operative procedure Gillies and Fraser devised a method of bridging the area of lymphatic block by means of a long strip of healthy skin and subcutaneous tissue with its lymphatics. This skin bridge is cut from the upper extremity. A bed is prepared, extending from the affected thigh to the flank, and into this the pedicled flap is most carefully sutured. When it has firmly healed into position the flap is detached from the upper extremity. The area on the arm from which the bridge is secured must be carefully repaired and may require skin grafting. The operation is potentially a severe one, which must be carried out in stages. In a few cases the immediate results were encouraging, but in the main have been disappointing and the operation has been abandoned.

The operation of lymphangioplasty with buried silk threads has not been a success in the management of this condition.

CHAPTER XI

THE SURGERY OF THE HEART AND GREAT VESSELS

By GEORGE A. MASON

PROGRESS in the surgery of the heart and great vessels has been spectacular and was made possible by the great developments in diagnostic, anæsthetic and resuscitatory techniques as well as in the clinical practice of surgery itself. The work now forms a considerable part of the work in the larger thoracic clinics. Formerly it was virtually limited to the relief of pericardial tamponnade due to hæmorrhage or inflammatory effusions, pericardiectomy for constrictive pericarditis, removal of emboli from the pulmonary artery, the treatment of aneurysms and the repair of cardiac wounds. Now operations are regularly undertaken for the correction or palliation of such congenital anomalies as persistence of the ductus arteriosus, coarctation of the aorta and congenital heart disease, as well as for some valvular lesions such as mitral and aortic stenosis and for the relief of myocardial ischæmia. The field is one of the great frontiers of medicine. Much work is being done to develop an artificial heart, which by maintaining the circulatory and respiratory functions whilst the heart is excluded from the circulation, would permit of direct access to the interior of the heart itself for an adequate period. Improved techniques for the repair of septal defects as well as for plastic procedures on the valves themselves would then be possible. Artificial cooling of the body is being increasingly employed—by some in conjunction with circulatory (by-pass) pumps. Tissue oxygen requirements are considerably reduced when the body temperature is lowered to 25° C. and it has been possible to arrest the circulation almost completely for relatively long periods (15–30 minutes) without obvious damage to the brain resulting. Cooling is not without danger and there is an increased risk of ventricular fibrillation. Cooling may be done by immersing the patient in iced water or by wrapping him in a "blanket" through which iced water is flushed Alternatively auto-transfusion may be used—the patient's blood being passed through a cold medium.

Angiocardiography, cardiac catheterization and blood gas analysis are amongst the diagnostic methods of special importance in the development of this work.

Angiocardiography consists essentially of the rapid introduction of a relatively large quantity of radio-opaque material (usually c-Diodrast) into the circulation through an arm vein, and the recording of its passage through the heart and great vessels by means of a series of X-ray films rapidly taken in two planes Anæsthesia is necessary for some children when tracheal intubation should be employed so that

artificial ventilation may be given should this—as may be the case—be required.

Cardiac catheterization must be carried out with the strictest aseptic precautions in an X-ray room so that the progress of the catheter to and fro as well as within the heart may be observed through the fluorescent screen. The equipment required includes venous catheters, a water or an electric manometer to measure the pressures in different situations, apparatus for measuring blood gas contents and syringes for collecting blood samples. Local anæsthesia suffices with adults but in a small child a full general anæsthetic may be required. So that blood gas studies may not be interfered with "Avertin" is probably the most convenient for this purpose. The catheter is passed rapidly under visual (X-ray) control and confirmatory pressure readings and blood samples (for gas analysis) taken in the cavæ, the right atrium, the middle of the right ventricle, the outflow tract of the right ventricle, the main pulmonary artery, one or both of its branches and at the furthest accessible point in the pulmonary field. This last reading (called variously the peripheral pulmonary or the pulmonary capillary pressure) is taken at a point beyond which the catheter cannot be passed and at which the pulmonary blood pressure falls and the oxygen saturation of the blood drawn back (through the pulmonary capillaries) approximates to the systemic arterial level. Of the complications which may occur, excessive blood loss, infection and air embolism are obvious and should be avoidable. Phlebitis and thrombosis of the vein used for the introduction of the catheter may occur. The heart's action should be watched on an electrocardiograph throughout; ectopic beats are common but ventricular tachycardia and even cardiac arrest may occur; the facilities for the treatment of these and for cardiac resuscitation should be available.

Preparation of patients for operations on the heart and great vessels involves consideration of the condition for which the operation is being undertaken, its direct consequences and the nature of any coexisting lesion, in addition to the problems of thoracic operations in general. Obviously, cardiac failure and arrhythmias must be controlled as far as possible but operation may have to be undertaken in the presence of either or both. Close co-operation with the cardiological physician and an expert anæsthetist is essential.

Anæsthesia for cardiac surgery.—With the rapidly increasing scope for cardiac surgery, the management of anæsthesia for these patients has assumed great importance. Cardiac arrhythmias are added to the problems associated with an open pneumothorax. In this type of surgery arrhythmias are commonly the result of direct stimulation and manipulation of the pericardium and heart itself, particularly those manipulations which dislocate the heart from its normal position or interfere with the coronary vessels. The complications of anæsthesia are largely the result of anoxia; if this is avoided,

it is surprising how well patients with grave heart disease tolerate anæsthesia and surgery.

In assessing these patients for surgery, the anæsthetist is particularly concerned with the exercise tolerance, and with the state of the myocardium. The reaction of patients to minor anæsthetics during the pre-operative investigations as well as a careful study of the cardiological and radiological findings give a fairly accurate indication of how these patients will behave during major surgery. Cardiac function should be improved as much as possible before operation by rest in bed and digitalis. Repeated aspirations may be required to relieve ascitic and pleural effusions, and mercurial diuretics are advisable for those patients with mitral stenosis whose lungs are congested. Patients with congenital cyanotic disease commonly have a respiratory infection with sputum which should be treated with antibiotics; some of these patients are better nursed in an oxygen tent for some days before and after operation.

Premedication with omnopon and scopolamine is well tolerated, the dose being varied for the physique of the patient. Comparatively large doses of morphia are given to the cyanotic children to reduce their metabolic rate and consequently their oxygen consumption. For the same reason the child should be kept cool during the operation, if necessary on a chilled water bed. Hypothermic techniques are developing from this principle.

The choice of anæsthetic drugs may be largely limited by the use of diathermy. Since the introduction of relaxant drugs it is possible to provide light anæsthesia with high concentrations of oxygen, with muscular relaxation, and with suppression of reflex responses, without the risk of explosion. With such a technique patients are awake and co-operative as soon as the operation is over. The drugs most commonly used are thiopentone, muscle relaxants, nitrous oxide, procaine and pethidine. A smooth induction and intubation avoiding hypoxia, hypertension and spasm is essential, and during operation controlled ventilation is practically indispensable during vascular anastomosis There is reason to believe that procaine given intravenously diminishes the sensitivity and irritability of the heart. Although it is customary to make electrocardiographic tracings during cardiac operations, the anæsthetist can gain valuable information as to the strength and quality of its action by observing the heart itself, especially during intra-cardiac manipulations. Blood transfusion is not always indicated, but one pint of cross-matched blood must always be available for immediate use in case of brisk hæmorrhage. Much more blood should be available in reserve Many surgeons prefer also to have at least one pint of fully oxygenated blood ready for immediate intra-arterial transfusion should the necessity arise. Each member of the operating team must be trained in cardiac resuscitation should cardiac arrest occur. Sterile syringes loaded with suitable restorative drugs and a defibrillator should always be ready.

Exposure of the heart or great vessels is mostly obtained through

a standard lateral thoracotomy, an antero-medial thoracotomy or by dividing the sternum either longitudinally or transversely.

The utmost gentleness must be employed when mobilizing or retracting the lung and in the handling of the heart itself. The latter is especially important as manipulation in conjunction with poor oxygenation due to blood loss or inadequate ventilation are ill tolerated and very liable to cause ventricular fibrillation or actual cardiac arrest. The vigor and rhythm of the cardiac action must be kept under the closest observation by surgeon and anæsthetist, as far as possible—towels, packs, etc., being arranged to facilitate this. Additional observations may be made by oxymetry and by means of an electrocardiograph with a "monitor" screen. Should the heart slow down alarmingly—ventilation being as efficient as possible—adrenaline (5–10 c.c. of a 1 : 10,000 solution) should be injected into the right ventricle. Should the slowing down progress towards or to arrest, massage must be started without further delay; this can best be achieved with the pericardium open and by compressing the heart between the surgeon's hand and the sternum or by using both hands. A rate of 60–70 beats a minute is possible and an effective pressure of 60 mm. Hg is necessary to protect the brain. The heart often starts to beat spontaneously again, feebly at first but with increasing vigour. Massage may be required for very long periods—for even as long as two hours—before hope of restoring the heart beat should be abandoned. It is almost always possible to restore it in a normal heart if full ventilation—oxygenation—is maintained. In obstinate cases repeated injections of adrenaline may be required but these become increasingly ineffective. Several minutes should elapse between each interruption, which should be minimal, of massage for injections, inspections, etc.; an electrocardiograph may indicate that the condition is one of ventricular fibrillation rather than asystole.

Should the heart go into a state of ventricular fibrillation, either primarily or during resuscitation, defibrillation is necessary. An attempt should be made in the first place to achieve this by injecting 5 c c. of 2 per cent. solution of procaine into the right ventricle followed by massage. If normal rhythm is not resumed thereafter, electric defibrillation should be attempted at the next interval of massage. The defibrillator uses standard electric current through a system of rheostat resistors delivering the current to the heart at approximately 1·5 amps. The electrodes are pieces of brass or copper measuring about 7 cm. in diameter, to each of which a handle is attached. One is then placed on each side of the heart and the shock applied by closing the circuit for a moment. During the moment when the current flows through the heart the muscle fibres are in a state of contraction; when the current is broken the ventricles are either in asystole or have resumed fibrillation. In the former case attempts to resume the heart beat by adrenaline and massage are made; in the latter further shocking is required. It cannot be too strongly emphasized that, to achieve success, full oxygenation is necessary throughout.

This entails free ventilation through a completely clear airway, and the maintenance of an adequate pressure in the arterial system by cardiac massage until the normal beat is resumed. A mechanical respirator, by ensuring adequate movement of the lungs and providing for absorption of carbon dioxide in a closed system using fresh soda lime, is invaluable in the maintenance of proper oxygenation in these cases.

THE PERICARDIUM

Pericardial tamponnade.—Fluid may accumulate in the pericardium under such pressure as to seriously embarrass the heart's action. The thicker walled ventricles are better able to withstand such compression, but this adaptation is at the expense of the venous inflow and the consequent effects of back pressure on the venæ cavæ becomes evident. These include distension of the neck veins, enlargement of the liver and cyanosis. The pulse becomes paradoxical, the blood pressure falls and there is increasing breathlessness. The area of the cardiac dullness is increased, the apex beat is obscured and the heart sounds are muffled. Such a picture of "cardiac tamponnade" may develop rapidly after wounding of the heart or pericardium or during the course of an inflammatory process which involves the pericardium. The pericardium has some power of adaptation but this is probably only significant with the more slowly accumulating effusions; there is no time for this to function during the course of a major hæmorrhage. Purulent pericarditis is comparatively rare but usually occurs, and with remarkable rapidity, in the course of severe infections such as empyema, septicæmia, etc., sometimes in the course of a few hours such a patient may become almost moribund and may well be lost unless the possibility of purulent pericarditis occurring is kept in mind and prompt measures for its relief instituted if its presence is confirmed.

X-ray examination will demonstrate the increase, sometimes immense and sudden, in the shadow and diminution of the pulsation of the heart Confirmation of the diagnosis is by pericardial paracentesis. When due to effusions, infections, etc., aspiration or drainage is required. Tamponnade is also associated with wounds and necessitates operative treatment which is dealt with separately.

Paracentesis repeated as required may suffice for the alleviation of simple effusions and in tuberculous cases, but septic pericarditis usually necessitates relatively urgent pericardiotomy and drainage in conjunction with the appropriate antibiotic treatment and chemotherapy.

Paracentesis pericardii.—So that incidental wounding of the coronary vessels or of the heart itself may be avoided and respiratory distress minimized, the patient should usually be in the semi-recumbent position.

The safest approach is through the costoxiphoid angle, the needle being passed upwards and backwards between the left costal margin and the xiphoid process (Fig. 253). Other sites commonly used are in

the fourth and fifth interchrondal spaces, one inch from the lateral border of the sternum. Sometimes a needle is inserted backwards and medially for this purpose in the fifth intercostal space lateral to the nipple-line; this should, however, be used only for the largest effusions and where there is X-ray evidence that the pericardium is actually distended so far laterally. Local anæsthesia is used. The needle chosen for the exploration and aspiration should be of wide bore and its tip only slightly bevelled. Suction should be applied through the syringe connected to the needle throughout the period of its introduction so that its entry into the pericardium may be recognized immediately—it being important that the needle should not project into the sac more than is absolutely necessary.

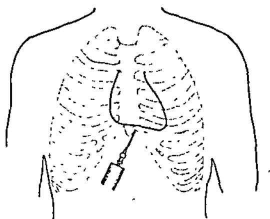


Fig. 253.—Paracentesis pericardii.
A needle with a short bevelled end is passed into the pericardium through Larrey's angle

Pericardiotomy.—Local infiltration anæsthesia with distant blockage of the 6th, 7th and 8th intercostal nerves is employed. It may be necessary to have the patient in a semi-recumbent position because of respiratory distress. The operation is, however, easier from the surgeon's point of view if it can be done with the patient horizontal. The best drainage is provided through the costoxiphoid route, the incision is made obliquely in the line of the seventh costal cartilage, about three or four inches of which are exposed and excised after division of the overlying soft parts. The xiphoid process is also excised and the attachment of the abdominal muscles stripped somewhat backwards and downwards to expose the usually bulging pericardium. The diaphragm is kept intact and neither pleura nor peritoneum are opened. The pericardium is opened and pus allowed to escape. If possible, two or three sutures of catgut should be used to secure the edges of the cut pericardium to the more superficial tissues of the parietal wound, to facilitate drainage and its maintenance.

An alternative left parasternal approach is favoured by some surgeons because they believe it permits of a wider exposure. Local anæsthesia is also used with the patient in the semi-recumbent position. A curved incision along the lateral border of the sternum starts at the third costal cartilage and is carried along the fifth space for some distance. The fourth and fifth cartilages are cleared of the overlying and attached muscles and then removed. The internal mammary vessels are ligated at the upper and lower margins of the field exposed. The fibres of the transversus thoracis are stripped laterally with the pleura which must not be opened. The pericardium is now exposed and widely opened, its redundant edges being sutured

to the fascial edges of the parietal wound so that drainage may be encouraged.

Drainage tubes should not be introduced into the vicinity of the heart but it is quite safe, if considered necessary for maintenance of drainage, to use a small roll of thin sheet rubber tissue drain which may be passed up behind the heart into the oblique sinus where pus may pocket. A simple saline or dry dressing is all that should be applied over the surface of the wound because the pericardium does not tolerate chemical antiseptics well. For the same reason, should irrigation be considered necessary, only saline should be used.

It is quite safe of course to instil penicillin (50,000/100,000 units) in 5 c.c. solution into the sac two or three times daily if the organisms responsible for the infection are sensitive thereto. It is necessary to maintain full supportive measures, and the appropriate antibiotics and chemotherapeutic measures should be used systemically in order to combat the underlying acute infection. With the relief of intrapericardial pressure there is usually an immediate dramatic improvement in the patient's general condition, at any rate in so far as cardiorespiratory function is concerned. Should the general measures taken to combat the underlying infection be successful, the discharge from the wound speedily becomes clearer, eventually ceasing, and the wound heals.

Constrictive pericarditis.—Mere obliteration of the pericardial space by adhesions—or even encasement of the entire heart in a calcified cage—does not necessarily cause disability and may indeed be beneficial when the blood vessels in these adhesions augment an otherwise deficient coronary circulation. There is, however, a group of cases in which obliteration is accompanied by gross thickening of the pericardium itself so that the heart becomes increasingly strangulated and its action so embarrassed that a condition of chronic cardiac tamponnade is established. This chain of events has followed such conditions as chronic pleural suppuration and possibly rheumatic infection, but it is thought to be more commonly a sequel of tuberculous pericarditis. Occasionally it may be part of a polyserositis.

The thickened and adherent pericardium which encases and strangulates the heart, is usually found to have a layer-like formation, probably representing the original parietal and visceral layers, between which are sometimes found cheesy accumulations and even pockets of pus which may be sterile There are often areas of calcification which may extend into the heart muscle. The ventricular muscle may be thinned and abnormally friable as a result of the pathological process. An essential mechanical feature of a heart encased in this way, at least when significant embarrassment exists, is that the effect is predominantly on the thinner walled, less resistant right side of the heart, the filling of which is impeded because the stout and powerful left ventricle being able to withstand compression more successfully in turn also compresses the atria and the venous

inflow tract. This mechanism is illustrated by those rare instances of "idiopathic" hypertrophy in the absence of valvular disease in which, as the pericardium is unable to enlarge adequately, the venous return becomes similarly obstructed; simple incision into the pericardium, allowing the heart to bulge freely into the left pleural space, relieves the obstruction. Similarly the racing greyhound which becomes heart bound, is relieved by incising the inadequate pericardium and allowing its hypertrophied heart to bulge freely within the pleura.

Sometimes, but probably only in a few cases, there may be localized significant constriction of the great vessels as they traverse the pericardium. Usually the constrictive effect is more generalized.

Constrictive pericarditis is usually encountered in children or young adults. The first indication may be a painless enlargement of the liver, followed later by œdema of the legs and ascites and a mild degree of breathlessness. These symptoms may progress until the patient becomes bedridden. A history of the initial onset of the original pericarditis may be unobtainable but at the other extreme there are those cases in which there is a continuous story of gross polyserositis or of a definite pericarditis, sometimes with effusion. There is usually some degree of cyanosis which may be extreme in advanced cases. There is always persistent filling of the neck veins even in the upright position. The pulse is paradoxical, tending to disappear during inspiration, of low tension and feeble, and there may be fibrillation. Poor cardiac output is indicated by a low blood pressure. The liver may be grossly enlarged and indeed in old-standing cases becomes cirrhotic. Whilst ascites may be controlled by tapping and mercurial diuretics, it tends to reaccumulate and increase. Albuminuria may be present. At X-ray examination the heart may be enlarged—but it is often smaller than usual and calcification may be recognized; restricted cardiac movement is recognized by "screening" and kymography. Cardiac catheterization and cardiographic studies are valuable in searching for localized constriction effects and for the confirmation of the venacaval pressure changes. Pericardiectomy offers the only prospect of reasonable relief. Ascites and œdema must be dealt with by fluid restriction and diuresis and, if need be, by abdominal tapping on the day before operation.

Care must be taken to avoid overdosage during both induction and maintenance of anæsthesia which is best given by the intratracheal method, if only for the facilities it provides for artificial respiration, should that be required either because of circulatory arrest or, as may well occur, because both pleural cavities may be opened. We find an intravenous procaine drip, 0·5 per cent. in 5 per cent. glucose, makes the heart less irritable and more tolerant of the necessary manipulation.

Operation.—There is no completely satisfactory incision for this operation. Splitting of the lower sternum up to the manubrium gives the most obvious exposure of the front of the pericardium and

the heart and if it is intended to do a detailed freeing of the great veins, it may be the best, but this is often neither necessary nor safe and the left side and posterior aspect of the left ventricle is not as accessible as may be desired. *A left transpleural approach*, between the fourth and fifth cartilages and ribs, with division of the cartilages, is preferred by some. Still the generally favoured approach is that *through the left parasternal incision*. The third, fourth and fifth cartilages may be divided close to the sternum or a tangential slice may be cut out of the sternum with a sternal chisel from the second to the fourth interspace and the flap retracted laterally with or without division of the corresponding ribs as far laterally as may be convenient; alternatively the third and fourth and fifth ribs and their cartilages may be resected for some inches and a "soft" flap of intercostal structures and periosteum, in which bone can regenerate, may be turned laterally. Recently transverse division of the sternum has been recommended

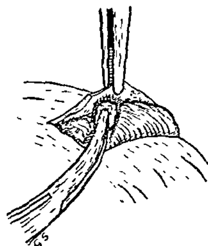


Fig. 254.—Pericardiectomy.

A portion of the thickened and adherent pericardium has been lifted up by a hæmostat after incision and is being stripped off the underlying heart by gentle dissection with a small swab held by another hæmostat.

The pleura should be stripped laterally as carefully as possible away from the pericardium; if it is torn it does not matter so long as this is recognized and dealt with. The left phrenic nerve should be identified and protected as its conservation is important. The thickened pericardium is incised carefully until a plane, in which there is some promise of cleavage being possible, is reached. Stripping should then be carried as far in every direction as may be possible so as to remove this first layer; removal may have to be done by blunt dissection with the finger or small swabs held by artery forceps (Fig. 254), or it may have to be done by sharp dissection; the thickened membrane or scar tissue replacing it usually has to be removed piecemeal or, at best, in strips. This thickened layer, separated laterally from the pleura as far backwards as may seem safe, must also be cut away from the diaphragm and the inner aspect of the sternum Within this plane there may be found pockets of cheesy debris or actual pus. After removal of this outer rind, the heart will probably give the impression of bulging through, though still restricted by the inner layer; this may also have to be removed as far as safety permits or at least its continuity divided in as many places as possible to free the heart adequately This layer must be dealt with in the most careful manner possible lest coronary vessels be damaged or the heart chambers entered. It is all too easy to strip or dissect into the various grooves in the heart wall when doing this and it is probably never possible to

remove an extensive sheet of tissue *in toto*. Should a heart cavity be entered, bleeding must be controlled, first by gentle digital pressure and then by interrupted sutures passed so as to avoid occluding coronary vessels; it may be helpful or necessary to use portions of the excised pericardial tissue or pieces of muscle to support these sutures. The left border, the front, diaphragmatic and posterior surfaces of the ventricular portion of the heart should be freed so far as can be done through the access available. If this much can be freed so that the thicker and more powerful left side of the heart can bulge freely, then it will usually be found that all that is required has been done. The scar is often adherent in the vicinity of the arterio-ventricular groove and serious damage to the corónary vessels may be done in attempting to dissect it away in such circumstances. Considerable further relief may be obtained if this constricting band is divided in one or two places. Another dangerous region where sharp dissection—as opposed to blunt stripping—should be avoided is near the pulmonary veins. Unless there is evidence from catheterization and angiocardiographic studies that the cavæ are constricted, it is usually unwise to attempt freeing them by dissection. There is generally very free oozing from the heart surface immediately after the removal of the scar; at times this may be alarming and it is then necessary to apply gauze swabs or even gelatine sponges to the raw area and pause a while from time to time. Gross arrythmia may occur whilst stripping is progressing, especially if much pressure on or distortion of the heart is necessary, but these are much less common and less marked since it became customary to administer procaine intravenously during these operations.

If the pleura has been opened, it is advisable to provide syphon drainage for 48 hours so that the inevitable oozing, which may be considerable, may drain away through the pleural cavity; for the same reason if the pleura has not been opened, a soft rubber tissue drain should be used to drain the wound itself. The wound should be closed in layers, preferably with interrupted sutures of absorbable material. A firm dressing secured by elastic strapping is used to support the wound An X-ray examination should be made immediately at the conclusion of the operation lest some unsuspected opening into the pleura on either or both sides causes a tension pneumothorax; if present, this must be corrected by removal of the air Blood loss and the need for replacement must be estimated carefully; it is important that the circulation should not be overloaded. Usually this is a matter that the anæsthetist will deal with during the operation, the necessary blood being given after the constriction embarrassing the right heart has been relieved; the latter is evidenced by improvement in the patient's colour, diminished tension of the neck veins and a rise in the systemic blood pressure. The patient should be nursed in the " Fowler " position and oxygen given until the need for it is no longer apparent, but at any rate for the first 24 hours, either by means of an oxygen tent or a " B.L.B." mask. Usually

no further abdominal paracentesis is required after operation except in those cases which only show benefit after a comparatively long period.

Where there is any suspicion that the underlying tuberculous process is active, a full course of streptomycin and P.A.S. should be given to "cover" the post-operative period because miliary dissemination has occurred after operation. Sinuses, either tuberculous in nature or in association with sequestra of calcified nodules, have also occurred in the scars of these operations.

Where myocardial damage has not been excessive and irretrievable cirrhosis has not occurred, the outlook after operative correction of the constrictions is excellent. It may be a matter of some months before full relief is experienced, but even those cases in which as much scar as would seem desirable has not been removed and a further operation envisaged, subsequent progress often makes this unnecessary. The average mortality of this operation is now about 15 per cent.

Wounds of the heart and pericardium.— Wounds of the heart caused by stabs or missiles are usually followed by bleeding into the pericardium, tamponnade speedily ensuing. In such cases the pericardium is rarely able to adapt itself and a comparatively small amount (less than 200 ml.) of blood may produce gross symptoms; at the same time this compression may control the bleeding to a considerable extent. If there is an appreciable communication between the surface wound and that into the pericardium, or between the latter and the pleura, the tamponnade effect may not develop and under such circumstances it is fortunate if any spontaneous control of the bleeding occurs whilst the patient is still a "clinical" problem. If there is evidence that spontaneous arrest of the bleeding has occurred—and perhaps this is best estimated by the clinical state and by estimations of the venous pressure repeated at short intervals—then expectant treatment may be justified. Antibiotics such as penicillin must be administered to combat the otherwise almost inevitable infection. After 24 hours the pericardium should be cautiously aspirated to diminish the tamponnade, a procedure which may require repetition a day or so later. The patient must be continuously and closely observed under such circumstances lest further bleeding occur and urgent operation be necessary. If there is gross hæmorrhage externally or intrapleurally, operation under general anæsthesia with facilities for massive blood transfusion is necessary.

If the bleeding is into a pleural cavity, then a transpleural approach on the side concerned is required. However, if the site of the external wound suggests with reasonable certainty that the left side of the heart is involved, an incision through the fourth interspace (with division and retraction of the cartilages above and below), or a left para-sternal incision (through which the third, fourth or fifth cartilages and adjacent parts of the same ribs are removed) may be employed. The pleura is dissected away if possible without opening the cavity,

but this is not essential, especially in cases when speed is important. If the site of the heart wound is in doubt, probably the best approach is through a sternal splitting incision; the pericardium is exposed and stay sutures should be placed in series on either side of the proposed line of incision in the pericardium so that the heart within the pericardium may be held forwards if need be later. Once the pericardium is opened speed is essential because, with the inevitable release of the tamponnade, renewed bleeding from the heart wound is almost certain to occur. An efficient sucker, rather than swabs, must be used to remove the accumulated blood so that the source of the bleeding may be recognized without delay. If the latter is from a coronary vessel, every attempt to control it by the application of a gelatin sponge under firm pressure must be made; ligation of coronary vessels is to be deprecated because of the risk of infarction; if ligation is unavoidable a pedicled strip of parietal pericardium should be tacked to the heart muscle by a few fine sutures so that supplementary vessels may be carried to the heart muscle as healing occurs. Wounds of a ventricle may usually be controlled by light digital pressure whilst silk sutures (size 00) are passed through the myocardium in one side of the wound, deep to the finger and out of the other side, and tied as a finger is withdrawn. (Fig. 255.) Bleeding from an atrial wound may require suturing over a strip of pericardium because the muscle is thin and friable. It is usually possible to control bleeding from an auricular appendix by the application of a light clamp across its base, when the laceration in its wall can be repaired by suturing. After arrest of the bleeding and repair of the heart wound, the pericardium and heart surface should be cleansed by saline irrigations and aspiration; all foreign material must be removed. The pericardium should be closed by a few sutures widely spaced to facilitate drainage; if this cannot be done without tension, it should be left unsutured. The edges of the original surface wound should be excised. A soft rubber tissue drain should be left down to the pericardium for 48 hours, and the wounds closed by interrupted sutures in at least two layers if possible.

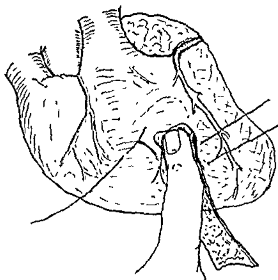


Fig. 255.—Repair of wound of the heart.

If the wound has involved the pleura, this should be drained until

the lung has re-expanded. Oxygen, by tent or "B.L.B." mask, should be given for the first 24 hours or until its administration is obviously no longer necessary. A full course of penicillin should be given. Frequent X-ray examinations, starting immediately after operation, should be made so that any pleural effusion, further pericardial bulging or pulmonary atelectasis may be detected and corrected without delay. With modern antibiotics, infection is unlikely, but should this occur secondary drainage may be required.

Missiles in the heart.—Foreign bodies of appreciable size may lodge in the heart wall or in one of its chambers. Removal is indicated lest they become emboli or cause bacterial endocarditis, recurrent pericardial effusions or act as foci for abscess formation in the heart wall. Operative exposures are deliberately planned according to the site of the foreign body, so as to permit adequate access with minimum disturbance of cardiac function by dislocation or distortion of the heart, and to conserve the thoracic cage. An inframammary incision along *the fifth left interspace with division of the fifth cartilage, which can* be extended downwards in a T-shaped manner so that the sixth and seventh cartilages may also be divided, is employed to give access to the front of the right ventricle; after opening the pleura and pericardium—which is usually adherent to the heart. Further localization of the missile by palpation is essential. An incision is then made through the heart wall over it, a large artery forceps then passed through to grasp and withdraw it. Except with small incisions in the heart, bleeding from which can be controlled by digital pressure prior to suturing, it is necessary to place a double row of stay sutures along the line of the incision before it is made, so that by pulling these across each other, hæmorrhage may be controlled until they are tied. It is advisable to sew a convenient strip or free graft of pericardium over the suture line to give extra support. 2/0 black silk "arterial" sutures on atraumatic round needles are used for these heart sutures The pericardium, if free, should only be lightly sutured so that drainage may occur into the pleural cavity which in turn should be drained (syphon) for 48 hours.

Harken recommends that when an approach further to the right or to the diaphragmatic surface of the heart is required, the intercostal incision may be extended by combining it with a transverse section of the sternum which may be later repaired with wire sutures; similarly, when access to the right atrium or to the right side of the ventricle is required, a similar incision on the right side is useful. All such operations, even when undertaken at a time of election, should be done under full antibiotic "cover" lest infection be lighted up by intervention

DEVELOPMENTAL DEFECTS

Patent ductus arteriosus.—The ductus arteriosus enables blood to pass from the pulmonary artery directly into the aorta during fœtal life whilst the lungs are in the non-ærated (atelectatic) state; after

birth when pulmonary ventilation is established this " by pass " is no longer necessary and undergoes obliteration. This obliteration is complete soon after birth in most instances but is delayed in about 1 per cent. of otherwise normal subjects beyond the first year. Where it thus persists it may do so through adult life but there is some reason for believing that in some instances it may become obliterated during later childhood. At any rate it is not as common in adults as in children and all the children in whom its persistence is diagnosed almost certainly do not develop fatal or even crippling complications. Its persistence does not always have serious consequences because cases are encountered where its presence has been diagnosed in older patients without any disability referable to the ductus; it is also probably possible for it to remain patent without physical signs or symptoms because a symptomless ductus is occasionally encountered unexpectedly in elderly subjects during intrathoracic operations for other conditions. Persistence must, however, be regarded as potentially dangerous, it carries with it all the dangers and risks of complications of an arteriovenous fistula. Cardiac enlargement, because of the heart's effort to maintain the peripheral circulation, and overloading of the pulmonary circulation are the most serious mechanical consequences of a persistent ductus and when they occur probably lead inevitably to cardiac failure, which may, however, be deferred until mid-adult life. A grave complication which seems to affect children and young adults especially—although its exact incidence is unknown—is bacterial infection, usually with a *Streptococcus viridans.* Such an infection has all the serious consequences of infective endocarditis—septicæmia and anæmia. It is often asserted that persistent ductus may cause retardation of growth but the evidence is equivocal

Diagnosis.—Clinically in the very great preponderance of these cases there is a characteristic to-and-fro " machinery " or " Gibson " murmur and palpable thrill in the second and third interspaces to the left of the sternum. Diastolic blood pressure is usually lower than normal and the " pulse " pressure correspondingly increased. Radiologically the heart may or may not be enlarged but the pulmonary artery shadow is always more prominent and the lung vascular fields may be more marked. Cardiac catheterization may reveal increased pressure and raised oxygen saturation in the main pulmonary artery. The catheter will often be seen passing through the ductus into the aorta A positive blood culture may confirm the presence of infection but other evidence of septicæmia may make the diagnosis obvious. The characteristic finding with angiocardiography is the " secondary " filling of the pulmonary artery from the aorta and on occasion the ductus itself may seem delineated in an oblique view.

Indications for operation.—The occurrence of infection is an absolute indication for operative closure of the ductus. The *Streptococcus viridans* is usually sensitive to penicillin and it is desirable

if possible to get the infection well under control before operating so that the risk of the ordinary surgical hazards of infection may be minimized. If the infection does not respond to a full " endocarditis " course of antibiotics, then operation should be proceeded with; in this connexion it should be recalled that, before the availability of penicillin, Tubbs showed that surgical closure of the infected ductus could be a most efficacious method of terminating such infection. Recurrent bronchitic attacks are possibly due to pulmonary congestion and are indications for treatment.

Cardiac enlargement, otherwise inexplicable, and increased pulmonary congestion as seen in the X-ray film are indications in young subjects for surgical closure even before other symptoms appear. In older subjects operation may be more hazardous because of the increasing fragility and adhesion to each other of the great vessels and of similar changes in the ductus itself. Failure may be considered to necessitate operative closure and under such circumstances the increased hazards will be taken fully into consideration before a decision is made. Whilst closure is recommended by many as a prophylactic procedure in cases without either disability or complications, it should be remembered that the published series show an overall operative mortality of between 3 and 5 per cent. It cannot be too strongly emphasized that prophylactic operations should be free from mortality and confined probably to children. It is important to realize the possibility of otherwise healthy young subjects developing cardiac neurosis and even semi-invalidism because of accidental recognition of the characteristic murmur. Cyanosis should be regarded as a contra-indication to operative closure; except when failure is established it usually means that the ductus has remained patent as a compensatory mechanism for some other developmental defect.

It must be emphasized here that closure of a persistent ductus arteriosus, whether by ligation or division, is never a minor operation, despite the unfortunate growth of an erroneous belief to the contrary during recent years. It is a major operation which carries with it certain grave hazards and an appreciable mortality, and should not be done except by those accustomed to dealing with major cardio-vascular problems within the chest and with every facility available for dealing with such crises as major hæmorrhages from the pulmonary artery or aorta, cardiac arrest, etc.

Operative details.—The patient is placed upon the right side with the left arm drawn well upwards and forwards to displace the scapula as far out of the way over the upper ribs as possible with moderate retraction. A standard posterolateral thoracotomy gives adequate access to the upper mediastinum through the bed of the fourth rib. The lung is retracted gently downwards and forwards to expose the mediastinum above the lung root. A few small lymphatic glands are usually seen in the triangle between the phrenic and vagus nerves and the lung root. The mediastinal pleura *and fascia* are incised over

the aorta from the level of the bronchus to above the arch and behind the vagus and recurrent laryngeal nerves as they cross the aorta. Fine silk sutures placed 1 cm. apart along the anterior edge of the pleuro-fascial wound in the mediastinum serve to retract the lung with the vagus and recurrent nerve—lying in the fascia—out of harm's way and expose the important part of the operating field. (Fig. 256.)

The ductus thus exposed must be carefully isolated from below medially and laterally by blunt dissection; the little lateral lappet of pericardium should be dissected forwards off the ductus. It should be clamped for three or four minutes to ensure untoward circulatory changes do not follow its closure. The ductus is now ready to be tied or divided, the decision as to which procedure is adopted being to some extent a matter of the surgeon's preference and the type of ductus present. A long narrow ductus may be tied or divided but a short wide ductus can probably only be dealt with safely and effectively by division and closure of its extremities Infection may make either ligation or division of a ductus dangerous. A ductus may be effectively tied by applying three or four double linen thread ligatures (size 20) around and carefully tying these close together. (Fig. 257.) Some surgeons prefer to use silk ligatures or to use two placed some distance apart, a minim of some sclerosing fluid like sodium morrhuate being injected between the ligatures or to transfix the ductus with a suture ligature between these ligatures. Care must be taken to avoid placing the ligatures too close to either the aorta or the pulmonary artery lest rupture occurs; the base of the cone where the ductus joins the main vessel is especially to be avoided. Should tearing occur during ligation it must then be quickly decided whether the bleeding is likely to be effectively controlled by the application of a suitably sited suture

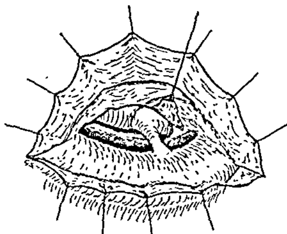


Fig. 256.—Patent ductus arteriosus.

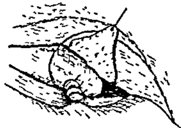


Fig. 257.—Ligation of ductus arteriosus.

Four double linen thread ligatures (size 20) have been tied tightly round the ductus.

ligature of 4/0 braided silk on a curved atraumatic needle or, as is much more probable, a repair of the aortic wall is indicated. In the latter event a finger should be gently applied over the tear until a Pott's toothed ductus clamp can be placed across the aortic base of the ductus and suturing it with 4/0 or 5/0 silk artenal suture on a small curved atraumatic needle. The aorta itself cannot be occluded probably for more than approximately 15 minutes lest serious damage to the spinal cord result. Therefore, should any repair of the aorta be necessary, a clamp, such as Pott's or Beck's, which allows the passage of blood whilst obliterating a portion of the vessel, should be used. Bleeding from the pulmonary artery end of the ductus can usually be controlled, first by gentle digital pressure until by gradual exposure the defect may be closed by appropriate suturing. Should this not suffice, it may be necessary to open the pericardium and control the bleeding by temporary application of a "Blalock" or bulldog clamp to the left pulmonary artery. It is necessary in some instances, where the ductus is shorter than its width, to divide the ductus and close it by suturing its ends; some surgeons prefer this method for most cases. Pott's (toothed) ductus forceps are applied to the ductus close to its pulmonary and aortic ends respectively. The ductus is next divided between the clamps so as to leave a cuff projecting beyond each. These cuffs are then sutured with a suture of 4/0 braided arterial silk suture on a small curved atraumatic needle, the bites of the suture being as closely applied to each other as possible so that the stump is completely closed The clamps are then removed. (Fig. 258) If any oozing occurs after removal of the clamps, a small piece of gelatin sponge is applied over the suture line with gentle pressure for a few minutes and usually suffices to arrest it, if not some supplementary suture may be required. The mediastinal pleura should be repaired with fine traumatic sutures After reinflation of the lung by the anæsthetist, the chest should be closed in the usual way and syphon drainage employed for the first 48 hours to drain away any effusion The patient who has had an uncomplicated ductus closed may well be allowed out of bed after 48 hours but with others each case will have to be decided on its merits, taking into consideration especially the question of cardiac infection and strain.

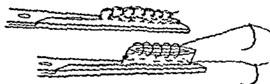


Fig. 258.—Division and suture of ductus arteriosus.
The isolated ductus has been divided between two Pott's ductus clamps and the projecting atraumatic stumps closed by *aller et retour* silk sutures (4/0)

Special complications may arise post-operatively in these cases The recurrent laryngeal nerve is not infrequently bruised during manipulation and temporary palsy of the left vocal cord occurs but clears up in a few days. Late involvement of the nerve in fibrosis around the ligature material has also been reported, as has apparently unrecognized destruction of the nerve during operation. Ineffective

coughing may cause atelectasis and require bronchoscopic aspiration. Formation of septic aneurysms between the aorta and bronchus has been reported after ligation.

Results.—The murmur and thrill always disappear immediately after occlusion of the ductus and the diastolic blood pressure, if previously lowered, approaches the normal. There is a drop in pulmonary artery pressure as determined by cardiac catheterization, an abolition of pulmonary congestion and diminution of the size of the pulmonary artery as seen in the X-ray film. If the heart was formerly enlarged it diminishes in size, the cardiothoracic ratio falling. If cardiac failure was a pre-operative feature, this improves. An associated endocarditis is usually cured. The mortality of the operation is in the vicinity of 3 to 5 per cent. Recurrence of the murmur, even after division, has been reported but if the ductus has been divided effectively or tied it is difficult to understand how this could occur. It is possible to envisage recanalization occurring where only one ligature has been used and more especially if this is of umbilical tape—a relatively broad material through which it is possible to conceive of a tenuous channel persisting through the inequalities of pressure application within the knot formed by the tape.

Dysphagia lusoria is a term applied to dysphagia due to a freak of nature. Developmental anomalies of the aortic arch may, by causing pressure on the œsophagus or trachea, give rise to symptoms of varying severity. Probably these anomalies only come to notice in this way in a minority of cases. Attention is usually drawn to their existence in young infants and the symptoms may subside as the structures involved become adapted. Surgical assistance may be necessary to save life or to make it tolerable. On the other hand, symptoms may not occur until much later in life when the vessels become thickened and dilated and when surgical treatment is of necessity more hazardous. The diagnosis is usually made as the result of radiological findings in the course of investigations for the elucidation of the presenting symptoms.

Double aortic arch occurs in those comparatively rare instances where the ascending aorta splits into two limbs which encircling the œsophagus and trachea to rejoin and form the descending aorta The trachea alone may be encircled Probably in the majority of cases no symptoms are caused but in a small minority—if there is insufficient room within the " ring "—it causes dysphagia and stridor, severe and repeated attacks occurring; these may be fatal unless the constricting ring is divided. It is possible through a left transpleural approach and a mediastinal dissection to expose the aorta. Usually apparently the innominate artery arises from the posterior limb of the arch and the left common carotid and subclavian arteries from the anterior. Division of the anterior limb between the origins of these vessels relieves the symptoms but Gross advises that in addition the

left common carotid artery should be held forward from the trachea by *anchoring it to the back of the sternum* by several interrupted sutures of silk lest residual symptoms persist.

Anomalous right subclavian artery may cause hesitancy in swallowing because of the pressure it exerts on the back of the œsophagus as it courses behind it from its independent origin as a separate branch of the descending aorta. A similar approach to that for "double aortic arch" will facilitate recognition of the presence of the anomaly. Simple division between ligatures will suffice to relieve the symptoms.

Coarctation of the aorta.—Coarctation, or congenital stricture of the aorta, occurs most commonly just below the origin of the left subclavian artery, about the point at which the ligamentum arteriosus joins the aorta to the pulmonary artery. There are two types of coarctation. The commoner or adult type is that in which the stricture is associated with complete, or almost complete, obliteration of the ductus. There is a more or less well-developed collateral circulation; whereas with the infantile type of stricture there is no marked collateral circulation in the lower aorta which the ductus enters below the stricture.

Even when the stricture is so severe that practically the whole of the circulation of the lower part of the body is maintained through collateral channels, it may be compatible with useful life and even with longevity. It is usually only in those who develop symptoms that the condition comes to notice. These symptoms are those due to the increased pressure, often severe, developing in the vessels above the stricture and the inadequacy of the blood flow below; they include headaches, flushings, limitation of effort and sometimes poor healing wounds of the lower limbs. Severe hyperpiesia above the stricture may cause atheroma and eventually cerebral hæmorrhage, the latter also occurring from rupture of associated congenital intracranial aneurysms; rupture of the aorta and the coronary vessels have been recorded.

The clinical findings are characteristic; there is an exaggeration of the pulsation over the precordium, the subclavian arteries and the suprasternal notch; the pronounced radial pulse contrasts with the diminished femoral and perhaps absent dorsalis pedis pulses; there may be tortuous pulsating vessels around the scapulæ Usually there is a great disparity between the blood pressure readings taken in the arms and legs, but even when this is not particularly striking there are probably always very striking differences in the corresponding tonoscillometric readings Radiological examination reveals typical notching of the lower borders of the ribs (by the enlarged and tortuous intercostal arteries) and aortic enlargement may be seen. Sometimes there may be some degree of left ventricular enlargement and, indeed in older cases with severe disability, this may be marked. The diagnosis may be confirmed by aortography which gives valuable information both as to the site and type of the stricture and the

presence of any associated arterial anomalies likely to complicate the operation.

Prognosis is very difficult to assess in individual cases but operative treatment should probably be advised when the diagnosis is made in young subjects, especially when the blood pressure in the upper limbs is markedly raised, or definite symptoms exist. On the other hand the operation is to be recommended with increasing reluctance for patients over 25 because marked hypertension of long duration leads to the development of atheromatous changes in the aorta of such severity and such cardiac enlargement as to make operation unduly hazardous or even impossible. Although operation has been found possible in patients as old as forty, it is certainly easier, safer and more likely to be successful in the younger patient.

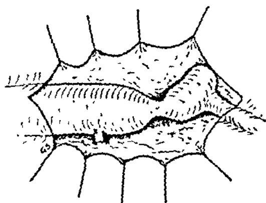


Fig. 259.—Coarctation of the aorta.

The mediastinal pleura has been incised and *with the underlying fascia* dissected forwards and held by a series of sutures. The aorta above and below the coarctation has been mobilized and its branches identified

Excision of aortic coarctation.—General anæsthesia is employed and facilities for massive blood transfusion should be available lest severe hæmorrhage occur. The patient is placed in the right lateral position and the left pleural cavity opened through a standard posterolateral incision, a long length of the fifth rib being removed subperiosteally. Hæmostasis must be meticulous, the chest wall being extremely vascular because of the extensive collateral circulation usually present. Should additional room be required the back ends of several ribs may be divided.

The lung is retracted forward after placing a large pack evenly against its posterior surface. The mediastinum is opened through a long incision made in the pleura *and fascia* overlaying the aorta, from about 2 in. above the aortic arch to about 3 in. or so below the coarctation. The edges of this incision are then dissected apart completely exposing the aorta; all bleeding points are carefully ligated. Fine sutures placed about 1 cm. apart in the anterior edge of this incision, left long and held by hæmostats, are then arranged to lie over the swab placed against the lung which is thus kept gently out of the operative field. (Fig 259.) The aorta and the lower part of the left subclavian artery are then mobilized by careful dissection, so that if the need arises, control tapes can be passed round them at any point from the origin of the left common carotid artery to about 2 or 3 in. below the stricture This mobilization requires recognition of and careful dissection round the origins of the upper aortic

left common carotid artery should be held forward from the trachea by anchoring it to the back of the sternum by several interrupted sutures of silk lest residual symptoms persist.

Anomalous right subclavian artery may cause hesitancy in swallowing because of the pressure it exerts on the back of the œsophagus as it courses behind it from its independent origin as a separate branch of the descending aorta. A similar approach to that for " double aortic arch " will facilitate recognition of the presence of the anomaly. Simple division between ligatures will suffice to relieve the symptoms.

Coarctation of the aorta.—Coarctation, or congenital stricture of the aorta, occurs most commonly just below the origin of the left subclavian artery, about the point at which the ligamentum arteriosus joins the aorta to the pulmonary artery. There are two types of coarctation. The commoner or adult type is that in which the stricture is associated with complete, or almost complete, obliteration of the ductus. There is a more or less well-developed collateral circulation, whereas with the infantile type of stricture there is no marked collateral circulation in the lower aorta which the ductus enters below the stricture.

Even when the stricture is so severe that practically the whole of the circulation of the lower part of the body is maintained through collateral channels, it may be compatible with useful life and even with longevity. It is usually only in those who develop symptoms that the condition comes to notice. These symptoms are those due to the increased pressure, often severe, developing in the vessels above the stricture and the inadequacy of the blood flow below; they include headaches, flushings, limitation of effort and sometimes poor healing wounds of the lower limbs. Severe hyperpiesia above the stricture may cause atheroma and eventually cerebral hæmorrhage, the latter also occurring from rupture of associated congenital intracranial aneurysms; rupture of the aorta and the coronary vessels have been recorded.

The clinical findings are characteristic; there is an exaggeration of the pulsation over the precordium, the subclavian arteries and the suprasternal notch; the pronounced radial pulse contrasts with the diminished femoral and perhaps absent dorsalis pedis pulses; there may be tortuous pulsating vessels around the scapulæ. Usually there is a great disparity between the blood pressure readings taken in the arms and legs, but even when this is not particularly striking there are probably always very striking differences in the corresponding tonoscillometric readings. Radiological examination reveals typical notching of the lower borders of the ribs (by the enlarged and tortuous intercostal arteries) and aortic enlargement may be seen. Sometimes there may be some degree of left ventricular enlargement and, indeed in older cases with severe disability, this may be marked. The diagnosis may be confirmed by aortography which gives valuable information both as to the site and type of the stricture and the

presence of any associated arterial anomalies likely to complicate the operation.

Prognosis is very difficult to assess in individual cases but operative treatment should probably be advised when the diagnosis is made in young subjects, especially when the blood pressure in the upper limbs is markedly raised, or definite symptoms exist. On the other hand the operation is to be recommended with increasing reluctance for patients over 25 because marked hypertension of long duration leads to the development of atheromatous changes in the aorta of such severity and such cardiac enlargement as to make operation unduly hazardous or even impossible. Although operation has been found possible in patients as old as forty, it is certainly easier, safer and more likely to be successful in the younger patient.

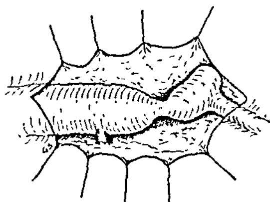


Fig. 259.—Coarctation of the aorta.

The mediastinal pleura has been incised and *with the underlying fascia* dissected forwards and held by a series of sutures The aorta above and below the coarctation has been mobilized and its branches identified

Excision of aortic coarctation.—General anæsthesia is employed and facilities for massive blood transfusion should be available lest severe hæmorrhage occur. The patient is placed in the right lateral position and the left pleural cavity opened through a standard postero-lateral incision, a long length of the fifth rib being removed subperiosteally. Hæmostasis must be meticulous, the chest wall being extremely vascular because of the extensive collateral circulation usually present. Should additional room be required the back ends of several ribs may be divided.

The lung is retracted forward after placing a large pack evenly against its posterior surface. The mediastinum is opened through a long incision made in the pleura *and fascia* overlaying the aorta, from about 2 in. above the aortic arch to about 3 in. or so below the coarctation. The edges of this incision are then dissected apart completely exposing the aorta; all bleeding points are carefully ligated. Fine sutures placed about 1 cm. apart in the anterior edge of this incision, left long and held by hæmostats, are then arranged to lie over the swab placed against the lung which is thus kept gently out of the operative field. (Fig. 259.) The aorta and the lower part of the left subclavian artery are then mobilized by careful dissection, so that if the need arises, control tapes can be passed round them at any point from the origin of the left common carotid artery to about 2 or 3 in. below the stricture. This mobilization requires recognition of and careful dissection round the origins of the upper aortic

intercostal and other branches. Some of these may have to be divided between ligatures, either because of injury or to facilitate the placing of clamps and excision of the stricture; there must, however, be the minimum possible interference with the collateral circulation in which these vessels play an integral part. Nylon tapes passed round the aorta facilitate this dissection. In the course of mobilization the ligamentum arteriosum or the remnant of the ductus will be exposed, and after the tissue around it has been cleared away, it must be divided between suture ligatures because there may be a small patent lumen communicating with the aorta. This naturally applies to "adult" coarctation only. When dealing with the infantile type, the ductus must obviously not be occluded at this stage. The stricture now being fully exposed, it is necessary to decide what particular *procedure should be adopted to improve the circulation in* the lower aorta. A straightforward narrow "adult" stricture which does not involve the origin of the subclavian artery should be excised and aortic continuity restored by an end-to-end anastomosis. Where the origin of the subclavian artery is close to or involved in the stricture, the latter may not be suitable for resection but it may still be possible to improve the circulation to the lower parts of the body by dividing the subclavian high up towards the neck, rotating it downwards and anastomosing it to the side of the aorta below the stricture. A similar procedure may be advisable when dealing with infantile strictures where the ductus must be divided only after an alternative circulation into the lower aorta has been established. Similarly, where an adult stricture is of such a length as to preclude a direct end-to-end aortic anastomosis after resection, subclavian-aortic anastomosis may provide a solution; otherwise the resected portion of aorta may have to be replaced by an aortic graft, obtained from a "bank", or a plastic tube Where resection has been decided upon the aorta should be clamped as far above the stricture as necessary to get an adequate lumen, close to or actually encroaching upon the origin of the subclavian artery Pott's (toothed) coarctation clamps are probably the least traumatic for this purpose. Another clamp which may be useful is that recommended by Blalock for use when the stricture is close to the subclavian; it is designed, on the same principle as Pott's clamp for pulmonary-aortic anastomosis, to permit continued flow along the subclavian whilst occluding the main channel opposite the mouth of that vessel; it is useful also to exert traction of the upper end of the aorta when this is needed to effect approximation of the aortic edges during the anastomosis. Another clamp should be placed upon the aorta about one or two inches below the stricture Both clamps should be applied slowly so that the circulation may be interfered with as gradually as possible When they have been applied confirmation of the possibility of bringing the aortic segments close enough together, after excision of the stricture, should be obtained by traction on the clamps (Fig. 269.)

Before suturing is commenced, *the aortic ends must be brought*

into close apposition by manipulating the clamps and from then on until the completion of the anastomosis an assistant must patiently and intelligently maintain them there, unless a special vice is used, so that no varying strains and stresses fall on the suture line. Fine (4/0 or 5/0) twisted silk sutures on curved taper point atraumatic ¾ in. needles are used for suturing the vessel ends together. Probably the safest and easiest method is to use interrupted everting sutures at intervals of about 1–1·5 mm. apart so as to make a flange junction. The first of these should be placed on the side of the anastomosis away from the operator. It should be passed from the adventitia through the intima into the lumen of the upper segment and then across to the lower segment passing from the lumen through the intima and out of the adventitia; it is then passed back through to the lumen and then across to the lumen of the upper segment again whence it is passed through the aortic wall close to the point at which the suture was commenced and is there tied gently and firmly so as to approximate and evert the edges; the ends of this first suture should be kept long as a handle The back side of the anastomosis is completed first and when the "half way" point is reached the ends of that suture also are retained as a handle. The front of the suture line is then completed similarly, but it is helpful to leave the last three or four sutures untied until they are all placed. Repeatedly during the suturing and before the final closure, the aortic segments should be gently syringed out with saline and heparin so that no clots or debris may be present within the lumen when the clamps are removed and the circulation restored.

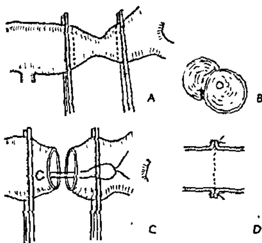


Fig. 260.—Excision of aortic coarctation.

A, Toothed Pott clamps have been placed on the aorta above and below the stricture which is then excised B, The excised segment showing that internally the stricture is much narrower than appears externally C, The ends to the anastomosed arc are approximated by a series of everting fine silk sutures (4/0 or 5/0) as shown in *D*

Maintaining an approximating force by gentle downward traction on the upper clamp, the lower clamp is released first. The suture line is thus tested for leaks. Usually bleeding only occurs from the suture pricks and takes up spontaneously as the anastomosis tightens by distension; if this does not immediately occur, gelatine sponge applied to the suture line and gentle digital pressure for three or four minutes usually suffice. Should bleeding be severe, the lower clamp must be reapplied and supplementary sutures inserted at the bleeding points and the procedure described be repeated. When all bleeding has been satisfactorily arrested the head of the table should be lowered and the upper clamp released slowly with the utmost caution lest a dangerously sudden drop of pressure occurs in the

coronary or cerebral vessels; the aorta is then buried in the mediastinum by repairing the pleura over it with fine interrupted sutures. The lung is inflated and the parietal wound closed in the usual way. The pleura should be drained for 48 hours. Blood loss will have to be adjusted as necessary during the operation.

In favourable cases, the pressures in the arms and legs approximate within a short time. The long term results are as yet difficult to assess but it is already appreciated that some hypertension may persist. It should therefore be remembered even during operation that there is probably little point in proceeding with a hazardous procedure merely as a surgical *tour de force*, unless the channel is likely to be considerably increased as a result. The mortality of this operation is higher in the older groups and, all told to-day, is probably between 20 and 25 per cent.

"Pure" pulmonary stenosis may exist as an independent condition apart from Fallot's tetralogy. There may be little interference with growth and symptoms may be minimal, or indeed absent, the defect only being suspected when a murmur over the pulmonary valve is heard during some chance examination. Such patients may remain free from symptoms, and even lead athletic lives, for years without becoming cyanotic. Many patients having atrial septal defects develop a right to left shunt in later life and become cyanosed. The picture may change to one of congestive failure with inter-atrial shunt and gross cyanosis. With more severe stenosis the right ventricle hypertrophying in an attempt to overcome the valvular obstruction considerable cardiac enlargement results. Eventually, right ventricular failure will result, but even without this these patients seem peculiarly liable to syncopal attacks and sudden death may sometimes unfortunately coincide with, and occur during, an operation. Sometimes it is difficult to distinguish between a severe pulmonary stenosis with a right to left inter-atrial shunt in a young subject from a case of Fallot's tetralogy. Pulmonary valvotomy for "pure" stenosis should be done before the inter-atrial shunt is reversed and before right ventricular failure has occurred. Probably a much commoner condition than was formerly appreciated, it may be that a majority of those patients coming to notice accidentally may never require surgical relief but should merely be kept under observation lest it be required later. Patients on the other hand who develop symptoms of cardiovascular disability, especially if there has been a syncopal attack, or those with appreciable cardiac enlargement, should be fully investigated. Should cardiac catheterization indicate that the right ventricular pressure is greatly raised and especially if it approximates or exceeds the sytemic arterial pressure, operation with a view to valvotomy (*see* p. 638) should be recommended as an urgent procedure. It is the only means by which pulmonary stenosis can be relieved.

CYANOTIC GROUP OF CONGENITAL CARDIAC DEFECTS

Surgical amelioration is now possible for a number of developmental defects of the heart and great vessels characterized clinically by cyanosis. The majority of these are variations of the " Tetralogy of Fallot ". The fundamental features of this syndrome are an overriding of the origin of the aorta so that it receives blood from both ventricles, a failure of development of the interventricular septum in that part of the arterial outflow tract from which the aorta and pulmonary artery take their origin, and some degree of obstruction of the pulmonary artery. This obstruction may take the form of an atresia of the pulmonary conus below the valve, an " infundibular " stenosis, hypoplasia of the main pulmonary artery and sometimes of its main branches, or there may be a simple failure of the cusps of the pulmonary valve to differentiate. " Valvular " stenosis and " infundibular " stenosis may coexist on occasion; the possibility of this must be kept in mind, and its presence confirmed or excluded both by pre-operative catheterization and angiocardiographic investigations as well as during the operation itself.

The fundamental disturbance in Fallot's tetralogy is that blood which should be destined for the pulmonary artery and lungs from the right ventricle is pumped from there mostly into the aorta because of the interventricular defect and the situation of the aortic origin somewhat over the outlet of the right ventricle as well as to the resistance of the pulmonary artery stenosis or atresia. Consequently, insufficient blood is passed through the lungs for oxygenation; in some cases where the degree of pulmonary hyopoplasia is extreme, the only blood reaching the lungs in significant quantity may be through bronchial arteries which anastomose with pulmonary artery branches in the lung. There is usually some abnormal, presumably compensatory increase, in these bronchial vessels in the hilus of the lung. In some cases an associated " mediastinal variococele " may be a formidable obstacle to dissection in the vicinity; whilst in others very large bronchial arteries, the size almost of a brachial artery, may replace the normal pulmonary artery.

Treatment.—Pure pulmonary stenosis, as Brock emphasized, can only be relieved by pulmonary valvotomy, which may also be the method of choice in certain cases of Fallot's tetralogy. For the latter condition, however, other operations require consideration and some choice of procedure exists. If one of the pulmonary arteries or one branch thereof is large enough, a fistulous communication may be established between it and a systemic artery. The anastomoses commonly employed include: one between a subclavian artery and a pulmonary artery—Blalock's operation—and one between the aorta and a pulmonary artery—Pott's operation. Should a " direct " operation be preferred to the establishment of one of these " shunts ", then pulmonary valvotomy for valvular stenosis and infundibular resection for infundibular stenosis may be done. The decision at

present is largely one of personal preference. The outflow of the right ventricle itself not being so impeded in the "Fallot" type of case as in "pure" pulmonary stenosis, a "direct" operation is not essential and establishment of a "shunt" gives excellent relief—possibly with a less hazardous operation, or so it is more generally believed at present. Where the hypoplasia of the pulmonary artery is extreme, valvotomy, even if possible, is pointless and an anastomosis must be established. Under such circumstances, where operation has been abandoned and the patient has recovered, late improvement of the cyanosis has been observed; Barrett, interpreting this improvement as being due to the establishment of vascular adhesions (such as occur with omentopexy) between the lung and parietes as a consequence of thoracotomy and handling, recommends that when unsuitable conditions are found at operation, this should be completed by stripping as much of the parietal pleura away as possible so that the lung may adhere widely to the raw parietes and vascular channels form. These operations have a mortality in the vicinity of 15 per cent.

Pulmonary valvotomy.—A definite diagnosis of pulmonary stenosis requiring valvotomy having been made, an anterior approach may be employed. The patient is placed in the supine position and according to preference, either a sternal splitting incision or an inframammary one, detaching the left pectoral muscles to give access to the third interspace, is used. A lateral approach is preferable, especially in those cases (such as Fallot's tetralogy) where it is desirable to leave a decision as to the exact procedure to be adopted until a full anatomical appraisal of the problem can be made. Then the patient is placed on the right side and the left pleural cavity opened through a standard postero-lateral thoracotomy in the fourth interspace. This incision is adequate for both the necessary pericardial exploration and for the Blalock, Pott's or Barrett types of operation and, if extended forwards to the sternum, is also quite adequate for a "direct" valvotomy

The pericardium is exposed extrapleurally by the sternal splitting incision and transpleurally by the others, and a small opening is made into it and 5 ml. of Xylocaine (2 per cent) is instilled into it and left there for four or five minutes after which the sac is widely opened to give adequate access. This topical application of Xylocaine supplementing the procaine given intravenously for cardiac operations, renders the heart less intolerant of any necessary handling and so probably diminishes the incidence of arrhythmias and the risk of arrest. Stay sutures of cotton or linen thread should be placed at intervals of 1 cm along the margins of the pericardial wound and retained to facilitate retraction of the pericardium and presentation of heart by traction on the former when necessary during the operation. Once the heart is exposed the diagnosis must be confirmed by inspection and palpation, the latter will reveal the maximum thrill at the site of the stricture in the first part of the pulmonary artery, this may

be constricted externally here contrasting with the post-stenotic dilatation which is usually presented. Sometimes by gently invaginating the artery beyond the stricture, the latter may actually be "picked up" between two fingers and the diagnosis confirmed.

If a lateral thoracotomy has been used, the surgeon should at this stage move to the other side of the operation table, i.e. to the front of the patient, a manœuvre which will greatly increase the ease with which the operation can be done. An incision, suitable for the lie of the valvotomy instruments must be selected in the outflow part of the ventricular wall, and infiltrated with procaine solution. (Fig. 261.) A cautious cut, about 1 in. long, is then made through the muscle. When the ventricle has been entered, a fine sound is passed through it to explore the strictured valve and ascertain the direction of the path into the pulmonary artery; when the latter has been

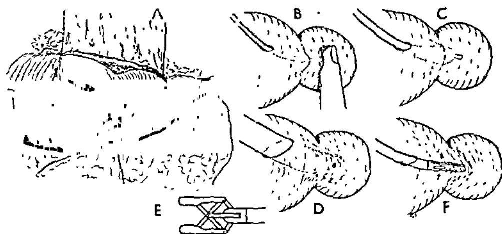


Fig. 261.—Brock's pulmonary valvotomy.

located, the first sound is withdrawn, and another shouldered one may be introduced to explore the face of the stricture. Should any interval of time elapse between the withdrawal of one instrument and the insertion of another, gentle digital pressure over the incision will control the bleeding. The site of the stricture and the direction of the approach to it having been fully appreciated, a valvotome of appropriate size is then passed through the stricture into the artery, care being taken to pass it in one direction only; success of the operation depends largely on the conversion of the membranous stricture with a central perforation into an efficient bicuspid valve—usually definite slight resistance and a sharp "plop" as the stricture is divided are felt. After the valvotome has been passed and withdrawn, a bougie of appropriate size for the artery, and if need be, a special dilator, are then passed in turn. There should be an

present is largely one of personal preference The outflow of the right ventricle itself not being so impeded in the " Fallot " type of case as in " pure " pulmonary stenosis, a "direct " operation is not essential and establishment of a " shunt " gives excellent relief—possibly with a less hazardous operation, or so it is more generally believed at present. Where the hypoplasia of the pulmonary artery is extreme, valvotomy, even if possible, is pointless and an anastomosis must be established. Under such circumstances, where operation has been abandoned and the patient has recovered, late improvement of the cyanosis has been observed; Barrett, interpreting this improvement as being due to the establishment of vascular adhesions (such as occur with omentopexy) between the lung and parietes as a consequence of thoracotomy and handling, recommends that when unsuitable conditions are found at operation, this should be completed by stripping as much of the parietal pleura away as possible so that the lung may adhere widely to the raw parietes and vascular channels form. These operations have a mortality in the vicinity of 15 per cent.

Pulmonary valvotomy.—A definite diagnosis of pulmonary stenosis requiring valvotomy having been made, an anterior approach may be employed. The patient is placed in the supine position and according to preference, either a sternal splitting incision or an inframammary one, detaching the left pectoral muscles to give access to the third interspace, is used A lateral approach is preferable, especially in those cases (such as Fallot's tetralogy) where it is desirable to leave a decision as to the exact procedure to be adopted until a full anatomical appraisal of the problem can be made. Then the patient is placed on the right side and the left pleural cavity opened through a standard postero-lateral thoracotomy in the fourth interspace. This incision is adequate for both the necessary pericardial exploration and for the Blalock, Pott's or Barrett types of operation and, if extended forwards to the sternum, is also quite adequate for a " direct " valvotomy.

The pericardium is exposed extrapleurally by the sternal splitting incision and transpleurally by the others, and a small opening is made into it and 5 ml. of Xylocaine (2 per cent.) is instilled into it and left there for four or five minutes after which the sac is widely opened to give adequate access This topical application of Xylocaine supplementing the procaine given intravenously for cardiac operations, renders the heart less intolerant of any necessary handling and so probably diminishes the incidence of arrhythmias and the risk of arrest. Stay sutures of cotton or linen thread should be placed at intervals of 1 cm. along the margins of the pericardial wound and retained to facilitate retraction of the pericardium and presentation of heart by traction on the former when necessary during the operation. Once the heart is exposed the diagnosis must be confirmed by inspection and palpation, the latter will reveal the maximum thrill at the site of the stricture in the first part of the pulmonary artery, this may

be constricted externally here contrasting with the post-stenotic dilatation which is usually presented. Sometimes by gently invaginating the artery beyond the stricture, the latter may actually be " picked up " between two fingers and the diagnosis confirmed.

If a lateral thoracotomy has been used, the surgeon should at this stage move to the other side of the operation table, i.e. to the front of the patient, a manœuvre which will greatly increase the ease with which the operation can be done. An incision, suitable for the lie of the valvotomy instruments must be selected in the outflow part of the ventricular wall, and infiltrated with procaine solution. (Fig. 261.) A cautious cut, about 1 in. long, is then made through the muscle. When the ventricle has been entered, a fine sound is passed through it to explore the strictured valve and ascertain the direction of the path into the pulmonary artery; when the latter has been

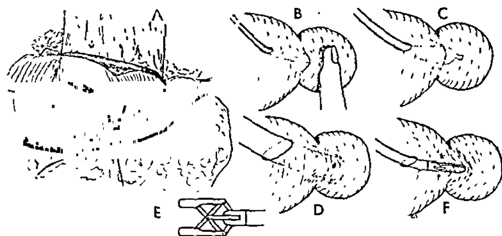


Fig. 261.—Brock's pulmonary valvotomy.

beec
of t
star

located, the first sound is withdrawn, and another shouldered one may be introduced to explore the face of the stricture. Should any interval of time elapse between the withdrawal of one instrument and the insertion of another, gentle digital pressure over the incision will control the bleeding. The site of the stricture and the direction of the approach to it having been fully appreciated, a valvotome of appropriate size is then passed through the stricture into the artery, care being taken to pass it in one direction only; success of the operation depends largely on the conversion of the membranous stricture with a central perforation into an efficient bicuspid valve—usually definite slight resistance and a sharp " plop " as the stricture is divided are felt. After the valvotome has been passed and withdrawn, a bougie of appropriate size for the artery, and if need be, a special dilator, are then passed in turn. There should be an

immediate increase in the flow of blood along the pulmonary artery after completion of the instrumentation.

These patients are liable to deterioration of the cardiac action at any time during the operation and especially before completion of the valvotomy, but even though the steps described for cardiac resuscitation may be required at any time, the operation should proceed as speedily as possible. Bleeding from the wound in the ventricle should be controlled by finger tip and a few interrupted sutures of 00 braided silk on a curved non-cutting atraumatic needle, should be passed through the myocardium deep to the finger which should then be removed and the sutures tied. The pericardial and

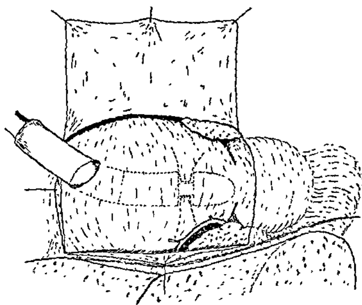


Fig. 262.—Brock's infundibular resection.

parietal wounds should then be closed in the usual way; it is probably better, if a transpleural approach has been used, to drain the pleura into a syphon bottle for 24 hours. There are no special post-operative complications The mortality of the operation is at present in the vicinity of 11 per cent, but is very much lower in children than young adults—a point to bear in mind when deciding when to operate upon individual cases under observation. The deaths are nearly all during operation from cardiac arrest and the survivors may be considerably benefited and capable of a good degree of activity.

Infundibular resection for infundibular stenosis.—The heart is exposed as for pulmonary valvotomy. The presence of an "infundibular" stricture is confirmed by external inspection and direct pressure estimations; there is usually a definite infundibular chamber present, if

this chamber is large enough and its wall thick enough, then an incision through its wall may give access to the stenosis. If the chamber is short or its wall thin, then approach must be through the wall of the ventricle some distance below the stenosis. Whichever site is chosen for the cardiotomy incision, the line of the latter should be infiltrated with procaine solution before it is made. The incision itself is made as for pulmonary valvotomy and a probe first passed through it to gauge the stenosis; then it is enlarged to admit Brock's infundibular punch, this is passed opened through the stenosis until the fibrous ring of the stricture is felt to slip back into the groove between the cutting edges of the instrument which is then firmly closed and withdrawn, bringing with it the resected tissue. (Fig. 262.) Light finger-tip pressure controls the bleeding from the cardiotomy wound which is then closed by a few transverse sutures of 00 braided silk as after pulmonary valvotomy.

PULMONARY SYSTEMIC ARTERIAL ANASTOMOSES FOR FALLOT'S TETRALOGY

After inspection of the great vessels at the base of the heart within the pericardium, assessment of the problem and the decision made to establish a systemic pulmonary arterial shunt, if possible the relationship and relative size of the pulmonary artery and the aorta or one of its available branches is considered. A quick glance will usually suffice to assess whether the aorta itself lies close enough to the pulmonary artery or whether one of its branches, usually the subclavian, is long enough to reach the pulmonary artery. The pulmonary artery must be exposed by mediastinal dissection, on the left side the left pulmonary artery itself lying below the aortic arch, above the bronchus below and behind the pulmonary vein. On the right side the upper division of the artery lies above between the bronchus and the superior vena cava and slightly overlapped below by the upper part of the upper pulmonary vein Approach to the pulmonary artery may necessitate division of some compensatory "bronchial" vessels lying beneath the mediastinal pleura, sometimes varicocele-like in their extent; these must be divided between ligatures one by one—a tedious procedure which, however, must be done most carefully lest severe bleeding confuse the dissection. Once the vessel has been well mobilized it should be gently occluded by a bulldog or Blalock's clamp for four or five minutes as a test to gauge the tolerance of the circulatory system, a prolonged period of occlusion being necessary during completion of the anastomosis. Should there be an inadequate pulmonary artery to the opposite lung, this test will speedily cause deterioration, corrected by removal of the clamp, of the patient's condition, the operation must be abandoned, unless a clamp is available whereby only partial occlusion of the pulmonary artery is needed. During this testing interval, dissection-mobilization of the aorta or of its branch chosen for the anastomosis should be

proceeded with. Should it be intended to make an anastomosis of the Pott type, the aorta opposite the mobilized position of the pulmonary artery should be mobilized and the branches arising from it over an extent of about 5 cm. divided between ligatures. If, on the other hand, the subclavian artery is to be used then an appropriate length of it should be mobilized from the mediastinum; it is usually necessary to tie off its vertebral and internal mammary branches although if a long enough piece of vessel can be obtained without doing so, they should be preserved so that there is minimal interference with the collateral circulation. The artery is then divided after temporarily occluding it by the application of a small bulldog

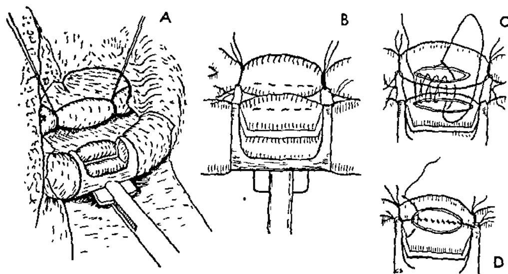


Fig. 263 —Pott aortic-pulmonary anastomosis.

clarity)

clamp to it just above its origin from the aorta; this clamp may tend to be pushed towards the periphery by the force of the blood pressure unless a ligature is tightly tied across its tips as they project beyond the side of the artery.

Pott (aortic-pulmonary) anastomosis.—A stout silk ligature is passed round the cardiac end of the mobilized length of the pulmonary artery so that it may be controlled by a slipping knot, a similar ligature is passed around the distal end of the vessel. (Fig 263.) A Pott's clamp of appropriate size is then applied to the portion of the aorta already mobilized. This clamp is so constructed as to present a lip of aorta from which the blood flow is excluded and at the same time a channel is permitted along the rest of the aortic lumen to maintain the circulation to the body below this level; when this latter channel is adequate, a definite thrill is palpable in the aorta below the clamp—a phenomena the presence of which must be

confirmed before the operation is proceeded with lest irreparable damage to the spinal cord and other vital strictures ensues. The clamp should be applied in such a way that the lip for anastomosis is presented towards the pulmonary artery. The ligatures applied to the pulmonary artery are tightened and the artery brought towards and maintained close to the lip of the aorta projecting from the clamp by tying the ligatures to the clamp above and below. Redundant connective tissue and adventitia are then dissected away from the two vessels. A parallel incision (rather than less 0·5 cm. long) is made in the adjacent portions of these vessels, which should then be syringed gently with normal saline. The stoma must not be larger lest too great a strain be thrown on the pulmonary circulation. A continuous arterial suture 4/0 or 5/0 braided silk on a curved atraumatic non-cutting needle is used to anastomose the vessels; this is started above, the deeper aspects of the vessels being brought together first. The suture is first passed through the aortic wall from without in and then back and tied, the short end being kept long enough for the final tying and pulled meanwhile gently out of the way by a fine hæmostat; the suture is then continued as an over and over stitch through both vessels, the bites being about 2 mm. apart, until the lower margin is reached; there it may either be locked or tied and the ends retained for tying the continuing suture; a new suture or the continuing one is then carried along to complete the anastomosis by a suture which may conveniently be everting—this is desirable but not essential—and finished by tying the loose end of the suture retained above at the commencement of the anastomosis. Some surgeons, sure of the perfection of the anastomosis, then remove the aortic clamp and the temporary ligatures on the pulmonary artery in rapid succession believing that the sudden strain completes the tightening and sealing of the suture line. Others, however, prefer to test this more cautiously and remove these controls in careful stages. Probably the safest routine is to slacken the distal pulmonary artery ligature and then, if no bleeding occurs, wait for four minutes and repeat the routine described. Supplementary suturing may sometimes be required but should be avoided if possible as additional perforations are of necessity made in the thin vessel walls and may themselves give rise to troublesome bleeding, usually such bleeding points in the main suture line occur because of inaccurate suturing. After the anastomosis has been completed and the controls removed, there should be a palpable thrill, distinct from that of the pulmonary stenosis, transmitted along the pulmonary artery towards the lung.

Blalock (systemic-pulmonary) anastomosis.—The pulmonary artery or its upper division on the right side is mobilized and test clamped in the same manner as for a Pott anastomosis. The subclavian artery which arises directly from the aorta, normally on the left side, may often be conveniently closed. Blalock prefers to use the subclavian which arises from the innominate artery, that is on the right

side in normal subjects and on the left in those with right sided aortic arches.

A length of artery which is long enough to prevent kinking must be prepared and redundant adventitia thoroughly removed from both it and from that portion of the pulmonary vessel to which the anastomosis is to be made. The mouth of the cut subclavian artery is approximated to the side of the pulmonary artery which is opened by an incision of corresponding size. (Fig. 264.) The central end of the pulmonary artery is controlled by a Blalock clamp and its peripheral ends by temporary silk ligatures. 4/0 or 5/0 arterial silk on atraumatic non-cutting needles should be used for the vascular suturing. The back of the suture line is completed at first; the suture starting at one end, the needle is passed through the subclavian artery from adventitia to intima, then through the pulmonary artery from intima to adventitia and then back through the pulmonary artery from adventitia to intima. Then back through subclavian artery from intima to adventitia and then tied. The bites of the suture should be about 1–2 mm. apart. Retaining the ends of the first suture long as a handle and marker, the back row of the anastomosis is completed by a series of everting sutures placed about 1–2 mm. apart. When the posterior row is completed, the anterior edges are similarly approximated so that a flanged union results. Intermittently throughout the performance of the anastomosis, it should be irrigated gently with normal saline solution. When completed the temporary ligatures on the distal end of the pulmonary artery are released and if no bleeding occurs, the clamp is gradually eased off and removed from the central end. All being well the bulldog clamp is then removed from the subclavian artery. Should minor bleeding occur from the suture line, gentle digital pressure over a fragment of gelatine sponge usually suffices to control it; larger leaks may require reapplication of the clamps and the insertion of additional sutures. A thrill can usually be

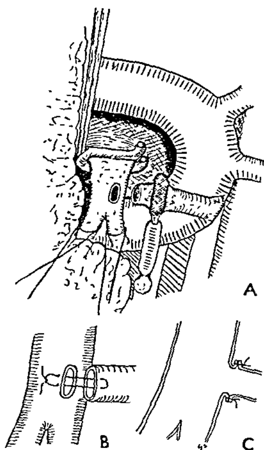


Fig. 264.—Blalock subclavian-pulmonary anastomosis.

A, The subclavian artery has been mobilized, divided and brought down ready to anastomose to the pulmonary artery The latter also has been mobilized and controlled proximally by a Blalock clamp and distally controlling ligatures have been placed around its branches B and C, The vessels are approximated by a series of everting fine silk sutures

felt over the anastomosis and may be conducted into the lung for some distance.

Whichever anastomosis is made, it is advisable to drain the chest for 24 hours afterwards so that the need for post-operative aspiration removal of pleural effusion is lessened. Frequent radiological examinations should be made during the first ten days after operation so that atelectasis, localized pleural effusions, pneumonic and other consolidations are not overlooked.

Atrial septal defects requiring closure are encountered with increasing frequency. Direct intracardiac repair is possible now that the heart can be temporarily excluded from the circulation under hypothermia. Success is claimed for several " blind " procedures which have been employed. One of these entails invagination of the right auricular appendage through the defect which is thus largely occluded. Another effects closure by sewing strips of fascia lata or pericardium across the defect from the front to the back of the heart. Others have relied on passing through the heart stout sutures which when tied forcibly approximate the two walls of the heart in the vicinity of the defect. Another method essentially consists in passing a stout purse-string suture around the right atrium to the left of the cavæ and in front of the right pulmonary veins after they have been dissected off the back of the right atrium; the lower length of this suture being brought through the atrium between the defect and the tricuspid orifice before tying it anteriorly. Success has been achieved also with direct open suture by working in the depths of a " sleeve " secured in the atrial wall.

Aortic aneurysms embarrass and threaten life by pressure on surrounding structures such as the trachea, bronchi, œsophagus and great veins or by erosion into the viscera or through the parietes. Recently clamps have been placed across the necks of saccular aortic aneurysms and the sacs either obliterated by Matas type suturing or actually amputated and the defects in the aortic wall repaired by direct suture. Similarly congenital non-specific and some favourable syphilitic aneurysms have been resected and the aortic continuity restored by the insertion of an aortic graft or plastic tube (Orlon). Several successes have been recorded but the techniques are necessarily complicated because, in addition to the double anastomoses involved, there is the problem of maintaining circulation through the distal aorta during their completion.

Many aneurysms are beyond such treatment when first encountered by the surgeon and only palliative treatment can be considered.

Partial mobilization of the aneurysms and wrapping cellophane (irritant variety) round them has been tried but with unconvincing results; the difficulty of mobilization at the points of greatest erosion are obvious.

Wiring is a simple palliative procedure for saccular aneurysms and can give great relief. The most useful method is that developed by

Colt. If the aneurysm is approaching the surface a trocar and cannula is passed into its interior through a small skin puncture incision using local anæsthesia. The trocar is withdrawn and free bleeding along the cannula demonstrates its presence in the sac. The first trocar is replaced by another which is essentially a cartridge containing a compressed, specially designed umbrella of bronze wire; by driving home the piston-like head of this trocar the wire is expelled into the aneurysm sac. There it immediately opens out like an umbrella frame which offers a large surface upon which clotting is initiated. Several such "umbrellas" may be required for large sacs. After withdrawal of the cannula a small firm pressure pad is fixed by strapping over the puncture. Relief of such symptoms as dyspnœa and orthopnœa is usually apparent within 24 hours and may be dramatic. The same method may be used also when an aneurysm can only be approached by thoracotomy.

Severe pressure symptoms due to aneurysm of the aorta when unsuitable for other methods may be given considerable relief on occasion by splitting the manubrium sterni vertically.

Innominate aneurysms, usually syphilitic, are still occasionally encountered. Although well-known successes have been recorded with the classical operation of proximal ligation this should now perhaps be regarded as a dangerous *tour de force*. Adequate relief can be given by converting these aneurysms, which are usually fusiform, into virtual saccular aneurysms of the aorta by the simple procedure of tying the subclavian and common carotid arteries just distal to the sac. A suitable Colt's "umbrella" is then inserted into the sac which becomes occluded by clot. The operation is done under local anæsthesia so that the vessels may be temporarily occluded for three or four minutes before the ligatures are tied lest symptoms of serious damage to the brain or arm appear. The subclavian artery is usually tied beyond the origin of the vertebral branch but this does not seem to lessen the efficacy of the procedure which has proved beneficial in a small series of cases.

MYOCARDIAL ISCHÆMIA

A variety of intrathoracic sympathectomies have been devised for the relief of angina pectoris At best these can only relieve pain but can do nothing to compensate for the underlying defect—progressive obliteration of the coronary vessels. Some success has attended efforts to establish an alternative or supplementary blood supply to the myocardium by promoting adhesions which it is hoped will carry anastomotic vessels to the smaller coronary branches—between the myocardium and some other vascular structure, such as parietal pericardium, lung, parietal muscle or omentum. The experimental basis of these methods and their clinical application have been elaborated by Beck in America and O'Shaughnessy in this country.

Many of these cases suffer from other degenerative vascular conditions and are not good subjects for operation, but by these methods probably about 30 per cent. receive sufficient benefit to resume gainful activity. The remainder, however, either die of some other vascular catastrophe such as cerebral apoplexy, renal failure or a further coronary thrombosis during the immediate post-operative period, or receive little benefit from the operation. A difficulty, especially tragic in otherwise fit patients, has been the prevention of a further coronary thrombosis during this period; but now with greater experience, especially in the anæsthesia and post-operative management, dangerous anoxæmic periods and falls of blood pressure are avoided and the risks of this complication, for which the graft can provide no protection at such an early phase, is less.

The simplest of these procedures is done with the patient lying flat, through a linear left parasternal incision. The third, fourth and fifth costal cartilages are removed. Incisions are made through these three cartilage beds and the pleura carefully stripped laterally by blunt dissection and three corresponding openings made into the pericardium. The parietal pericardium is abraded with a special roughened steel rasp and finely powdered asbestos blown over the surface of the heart. Harken alternatively claims that better vascular penetration occurs if the epicardium is destroyed by careful swabbing with pure phenol which also relieves post-operative pain by causing local anæsthesia. The pericardial sac is drained for 48 hours and the wound closed in layers.

General anæsthesia should probably always be used for these cases to ensure full oxygenation throughout and to avoid a long period of anxiety and fear which might of itself precipitate an anginal attack.

More robust patients can be dealt with more effectively through a left lateral thoracotomy through the bed of the seventh rib. The lung is retracted upwards and the pericardium opened and its inner parietal surface abraided. In addition to powdering or carbolizing the myocardium, strips of pericardium can also be sutured to it (pedicle grafts). All these procedures where an initial surface hyperæmia is induced probably benefit the myocardial circulation *immediately by the* greatly increased intercoronary anastomotic flow which experimental work suggests occurs under such circumstances and may account for the relief which some of these patients claim to experience from the early post-operative period. This intercoronary anastomosis is believed to be further benefited by the partial occlusion of the coronary sinus. This may be done by passing a stout silk or Orlon ligature on a fully curved needle through the atrial wall deep to and around the sinus just before it disappears into the heart wall, and tying it tightly over a probe of 3 mm. diameter.

Beck has more recently developed another procedure which is of greater magnitude and should be reserved for younger and otherwise fit subjects handicapped only by their angina and without evidence of serious myocardial damage. This requires two operations at an

interval of three weeks. At the first the pericardium is opened, as already described, through a left lateral thoracotomy and a ligature passed round the coronary sinus but left untied. The sinus itself, distal to the ligature, is then anastomosed to the descending aorta either directly or by means of a short autogenous vein graft of about 5 mm. diameter. Special toothed clamps are placed on both sinus and aorta so that whilst presenting lips for the anastomosis the flow along the main vessels themselves is not interrupted. Standard techniques for vascular suture are employed. Three weeks later the chest is reopened and the coronary sinus is narrowed by tying the ligature, already inserted, over a 3 mm. probe. At first a high proportion (30–50 per cent.) of these grafts were found at the second operation to be thrombosed, but in his later series Beck seems, by making a circular opening rather than a linear cut in the aorta when making the anastomosis, to have overcome this trouble. Should the graft be thus thrombosed, after ligation of the sinus, the pericardium and myocardium should be abraided, etc., as already described. Patency of these grafts can be recognized clinically by a loud murmur over the middle of the back and when this is present the associated clinical improvement has been excellent. The mortality of this operation done on fitter subjects has been, if anything, less than that associated with the earlier simpler procedures. Explanation of its success is not yet completely clear. Experimentally it seems that some reversal of the circulation does occur but it is probable that some benefit derives from improved intercoronary flow and by vascular adhesions forming between the epicardium and the pericardium.

RHEUMATIC HEART DISEASE

The impediment imposed by valves narrowed as a consequence of rheumatic disease, to the circulatory flow, is progressively crippling and eventually fatal. Many cases of mitral stenosis can now be relieved by the operation of commissurotomy sufficiently to resume full normal activity Some cases of aortic stenosis have been similarly helped but the method is not yet as well established.

Mitral stenosis.—All grades of disability are encountered. At one end of the scale there are those with such advanced cardiac and secondary changes that surgical interference can only accelerate the inevitable end, whilst at the other there are those in whom the only manifestation of the condition may be the possession of its stethoscopic signs and for whom surgery is at present unjustified. If moribund and trivial cases are excluded, three groups of cases remain which may benefit considerably from operation. The first includes those with slight symptoms but who on careful interrogation prove to have appreciable curtailments of activity and earning capacity, they have little or no pulmonary congestion and the cardiac catheter may reveal only slight elevation of the pulmonary arterial pressure. The

second includes those with rather more marked symptoms and lower exercise tolerance, who consequently have had to give up heavy work and all except the most moderate activity. The third group consists of those with severe disabling symptoms precluding all work; those with severe pulmonary congestion and those in whom there have been episodes of pulmonary œdema. The refinements of selection of cases for operation cannot be gone into fully here but these three groups include most of those suitable. Active rheumatic disease is probably a contra-indication. Other marked valvular disease is not necessarily a contra-indication. Operation should not be done in the presence of right heart failure. If this fails to respond to medical treatment, sometimes considerable benefit follows ligation of the inferior vena cava; this is best carried out under spinal anæsthesia, the vein being tied extraperitoneally just above the confluence of the common iliac veins.

There is no effective surgical treatment at present for mitral regurgitation. Neither its presence nor absence can be diagnosed with certainty but it seems to be more commonly encountered in those cases where there is calcification of the valve, marked cardiac enlargement and a systolic murmur conducted out to the lung bases. Recognition of paradoxical atrial filling by X-ray screening may be possible. Electrokymography or direct manometric readings obtained from the left atrium by transbronchial or dorsal puncture may be helpful but these methods are not yet in general use. Unsatisfactory though this is and even whilst nothing can usually be done to improve regurgitation at an operation which may prove necessary, cardiotomies have to be undertaken because occasionally an effective valvotomy for tight stenosis is achieved in cases where regurgitation is wrongly diagnosed.

Auricular fibrillation is not of itself a contra-indication to operation. Pregnancy may be a serious complication of mitral stenosis, often precipitating failure. Should this occur, especially during the early months, valvotomy should be proceeded with as soon as some degree of stabilization has been achieved to avoid relapse. Previous embolism is not a contra-indication but post-operative embolism is perhaps more common in those who have had emboli previously.

MITRAL VALVOTOMY

The operation may be done through a standard left postero-lateral thoracotomy incision, but a convenient approach is through an antero-lateral one. The patient is placed on the right side and inclined slightly backwards with the left arm lying by the side. The breast is retracted upwards and a curved submammary incision is made. The pectoral muscles are divided in the line of the incision or their origins detached from the ribs and the fourth rib is exposed. An incision is made through the periosteum of the rib, and over the cartilage, from the sternum to the mid-axillary line, and the inner surface of the rib and cartilage stripped with the aid of a periosteal

separator. The pleura is opened through this rib bed, the internal mammary vessels tied if necessary and the wound widely opened with a self-retaining retractor. Excess of pericardial fluid is allowed to escape through a small incision anteriorly, and 5 c.c. of 2 per cent. Xylocaine is instilled into the pericardium. The pericardium is then opened by a long incision behind and parallel to the phrenic nerve, extending to the pulmonary artery above to the lower part of the left ventricle below. The edges of this incision are held open by a series of fine cotton or silk sutures grouped in retaining forceps for retraction. A medium silk suture is passed in purse-string fashion around the base of the auricular appendix (Fig. 265). Should the latter not seem large enough to allow the passage of the finger within it, the suture should be on the postero-lateral side coming well down towards the upper pulmonary vein; in this case the entry to the atrium will be made through a longitudinal incision in its lateral wall extending backwards towards the vein—although always within the site mapped

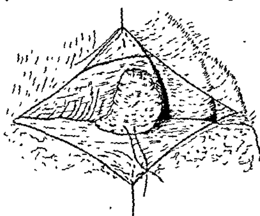
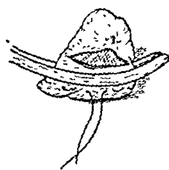


Fig. 265.—Mitral valvotomy.
A purse-string for security has been placed around the base of the left auricular appendix.



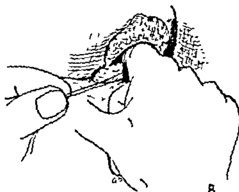


Fig. 266.—Mitral valvotomy.
A, A clamp has been applied around the auricle beyond the security purse string
B, The clamp has been carefully released to allow the finger to enter the atrium.

out by the purse-string safety suture, which will under such circumstances have to be relied upon entirely to control the cardiotomy wound around the finger. Usually, however, the appendix is of adequate size, then a non-crushing clamp is applied across its base and an incision made parallel to and about 1 cm. beyond the clamp. (Fig. 266.) The appendix is then flushed out with saline and the presence of clots noted. If the lumen is clear the finger is inserted

without more ado after release of the clamp. Should loose clots be present they must be aspirated or picked away, a proceeding that may be greatly assisted by releasing the controlling clamp and allowing the blood to gush out freely. After the finger (usually the index but occasionally it may be the little finger) has been inserted, a tactile exploration must be made. The situation, type and size of the stenosis

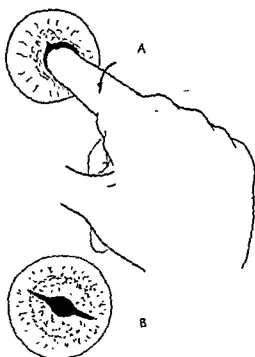


Fig. 267.—Mitral valvotomy.
A, The finger is pressing against the aortic commissure of the mitral valve to split it B, The valve after successful splitting

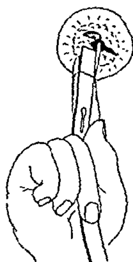


Fig. 268.—Mitral valvotomy.
The Bailey knife is being used to start the split of the lateral commissure. The hook has been engaged below and the guillotine blade is about to be shut.

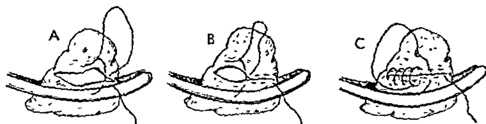


Fig. 269.—Mitral valvotomy.
Closure of the auricular wound by *aller et retour* everting suture.

and the presence or absence of regurgitation must be noted. Should a laminated clot be encountered at the site of the cardiotomy, no attempt should be made to remove it; it is probably much safer to incise straight through it and pass the finger towards the valve with the [illegible]

[illegible] which may be detached enter the cerebral circulation.

The aortic commissure is more likely to be split if it is dealt with first (Fig. 267); the finger tip should be pressed firmly against it when it will either give easily or obviously requires the assistance of a knife. Should this be necessary Brock's small knife is probably the best; it must, however, just be used to start the split by nicking into the commissure, digital pressure only being used for completion.

When the split has been completed or when it is obviously not going to succeed, attention should be turned to the lateral commissure. Similar digital pressure often suffices to obtain a satisfactory split. Should this not be so an attempt must be made to start it also by cutting; for this purpose the Bailey hooked guillotine is probably the easiest to use. (Fig. 268.) An adequate and efficient valvotomy is frequently achieved where it has only been possible to split the lateral commissure. Whilst the finger may remain in the atrium for considerable periods, it must not be allowed to linger unnecessarily in the valve orifice, as this completely interrupts the circulation and may initiate cardiac arrest. Dubost recommends the use of a special dilator rather than a knife for very " tough " stenosis. On completion of the valvotomy the finger is withdrawn from the atrium, bleeding being prevented by reapplying the auricular clamp or tightening the purse-string suture, which in any case is tied if the appendix is amputated. (Fig. 269.) If the auricular appendix is small or thrombosed it should be amputated and, after tying the purse-string, the stump should be oversutured. If the appendix is large and healthy, the incision in its wall should be repaired by an *aller et retour* everting silk suture. Even if the appendix is subsequently obliterated (which is by no means certain) its retention provides a useful handle should further exploration of the left atrium ever be necessary later. The importance of using the " security " purse-string suture, which should bite through the atrial wall, cannot be too strongly emphasized. It provides an invaluable handle should the base of the auricular appendix or the atrial wall tear during manipulation. Traction on this handle minimizes hæmorrhage and helps in the presentation of the torn wall for suturing. Such tears may be largely avoided if care is taken to avoid stretching of the incision by the inserted finger, which should rather take the atrial wall in toward the valve.

The pericardium should only be partly closed, sufficiently to preclude cardiac dislocation. Complete closure of the pericardium may result in troublesome pericardial effusions requiring treatment later. The thoracotomy wound should be closed in the usual way, provision being made for syphon drainage during the first 48 hours. Post-operatively these patients tolerate respiratory embarrassment badly and may require nursing in an oxygen tent. Pleural effusions must be constantly watched for and removed. Hæmoptysis and retained secretion may precipitate atelectasis; hence, tracheal and, if need be, bronchoscopic aspiration should be done if there is any evidence of bronchial secretions accumulating. Embolism occurs post-operatively in about 5 per cent. of these cases, in some immediately after the

valvotomy, in others during the subsequent 24 hours. An intravenous procaine drip, by diminishing associated arterial spasm, may minimize the consequences but the larger peripheral emboli may require surgical removal. Auricular fibrillation present before operation occasionally disappears thereafter. Transient fibrillation occurs fairly frequently during the post-operative period and in a few the arrhythmia remains as a permanent feature. Unless the operation is withheld from all except the most favourable cases, the mortality is about 10 per cent. Of those who recover and in whom a satisfactory split has been achieved, about 25 per cent. are so improved as to be almost indistinguishable from normal. About 45 per cent. are greatly improved and most of the remainder show some improvement, only a small number are not improved and in these the valves usually prove to have been dilated rather than split. It has been necessary to repeat the operation for recurrence in a small number of cases.

Aortic stenosis.—At first regarded as a contra-indication to mitral valvotomy is now itself being treated surgically. It is probable that a significant proportion of these cases is congenital rather than rheumatic in origin—a fact of some importance because strictures of the former type tend when split to become bicuspid rather than tricuspid as with the latter type for which Bailey has devised a special triradiate valvotome. The mortality of aortic valvotomy at present is higher than that of the mitral operation and the results are not so consistently good. Briefly, an incision, controlled by a gently held purse string, is made in the lateral wall of the left ventricle about 3–4 in. above the apex and between obvious coronary branches. A cardiac probe is passed through this incision and guided up the interventricular wall to the aorta where its presence is confirmed by palpation of the aortic wall by the fingers of the surgeon's left hand placed astride the pulmonary artery above the base of the heart. The correct path to the aorta avoiding the mitral valve having been learned, the probe is withdrawn and replaced by a suitable bougie or dilator which is then passed through the stricture so as to split it into two or three cusps. Bailey's special valvotome is claimed to ensure such splitting as opposed to mere disruption which is followed by a serious and probably fatal degree of regurgitation. Emboli detached from the structure are very likely to lodge in the carotid branches, hence compression of these vessels during the intracardiac manipulation is especially important.

Attempts have been made to relieve aortic regurgitation by passing strips of pericardium through and across the base of the aorta and by the introduction of plastic valves into the descending aorta but these procedures are still in the developmental stage.

CHAPTER XII

PRINCIPLES OF THE OPERATIVE TREATMENT OF MALIGNANT DISEASE

By W. SAMPSON HANDLEY

The fundamental starting-point for the operative treatment of malignant disease is *the fact that cancer is a disease of local origin* spreading gradually to distant parts. It is not a systemic or blood disease, as the earlier pathologists thought; if it were, the surgeon would have no part to play in its treatment. It may be admitted that operation is a clumsy weapon wherewith to fight the invisible and microscopic extensions of such a subtle disease. The fact remains that at present for some varieties of cancer it is still the only trustworthy weapon. Radiological treatment has, however, in some directions made great strides and is dealt with in a separate article by Prof. B. W. Windeyer in Volume II.

We trace briefly the various stages through which cancer surgery has passed.

Simple excision of the primary growth.—As soon as the progress of clinical observation had made possible the recognition of malignant growths, the surgeon followed his natural impulse to cut out the lump. Velpeau's description of his method of operating on breast cancer, dated 1853, may be taken as illustrating this primitive method. "Plunging in a straight bistoury," he says, "I, with one stroke, divide all the tissues to the lower surface of the tumour. Two of these parallel incisions enable me to include the tumour in an ellipse, and to separate it like a slice of melon. In this way the wound is more uniform and the proceeding more rapid."

Operations of this character, restricted to cutting out the lump, have from the earliest times been followed by a very occasional success probably because the removal of the bulk of the malignant tissue enables the natural resistance of the body to deal with what is left. But the method is like attempting to extirpate turf with a mowing machine, and little more hopeful

It might be thought that simple excision of the obvious lump is nowadays never practised This is far from being the case. In one week, some years ago, two cases in which it had been used for breast cancer, the greater part of the breast being left behind, came under my observation Such cases are the handiwork of the "occasional" surgeon. But in melanotic sarcoma the same simple operative recipe is still followed, even by trained surgeons, and with deplorable results. There are, of course, cancers trenching closely upon vital and irremovable organs in which a close excision of the lump represents all that is surgically possible

Charles Moore's paper on "Inadequate Operations"* affords material for judging the results of "cutting out the lump" in breast cancer. Among ten cases in which a cancer was excised from the breast, the disease returned in nine in the remaining portion of the breast, and in one in the axillary nodes alone.

It has been suggested that the primitive method of limited excision would be satisfactory if supplemented by radium tubes buried round the periphery of the operation area. Some surgeons are trying the combination, but its value cannot yet be assessed. It is my impression that in breast cancer axillary recurrence and brawny arm are likely sequelæ.

Excision of the primary growth with a definite margin of healthy tissue.—The next stage in the surgery of cancer, based on the unsatisfactory results of the primitive method, was free excision of the primary growth with a margin of healthy tissue. In breast cancer this extension of the operation was described as an "amputation of the breast". The use of the term "amputation" indicates a lopping off of the organ without regard to anatomy or pathology. In mammary cancer little improvement in results was secured. Moore states that, in three cases of complete removal of the whole breast, return of the disease cutaneously or subcutaneously, confined to one of the flaps, took place in two; in the other the disease recurred in the axillary nodes.

Simple free excision of the primary growth has not been entirely superseded. It remains the method of choice for some malignant tumours, the method of necessity for others. It is adopted in rodent carcinoma, which has no tendency to disseminate. It is suitable for dealing with malignant growths originating in areas where dissemination is prevented by previous extensive destruction of the lymphatics, as in lupus carcinoma and some X-ray carcinomata; and for the fibrosarcomata, which have little tendency to disseminate. Sometimes it may be justifiable as a palliative to remove the offensive and obvious external growth until the patient succumbs from dissemination untroubled by local recurrence. In many internal cancers, free excision of the primary growth may be all that is surgically possible. Successful excision of the head of the pancreas for carcinoma is a recent achievement of American surgery, standing to the credit of A. O. Whipple.

Monobloc removal of the cancer and the affected nodes enclosed in a sheath of normal tissue.—The beginning of a third stage of cancer surgery is to be traced in the paper read before the Royal Medical and Chirurgical Society in 1867 by Moore, who was then Surgeon to the Middlesex Hospital. He showed that recurrence after the operation is due, not to an organic or constitutional taint, but to imperfect removal of the primary growth and its surrounding satellite nodules. He insisted that the growth, with all its ramifications, must

* *Med.-Chir. Trans.*, 1867, l, 245.

be removed in one piece, and must not be seen or cut into during the operation. He enunciated the necessity in every case of removing the whole breast, along with unsound adjoining structures—skin, lymphatics, fat, pectoral muscle, and axillary nodes. After delimiting the unhealthy skin, he undermined the skin-flaps so as to detach the breast from its circumference towards its centre. He did not, however, state precisely how he would define "unsound adjoining structures" requiring removal, nor did he give an exact description of his operative method. It was perhaps for these reasons, or because of the danger of extensive operations in the pre-Listerian period, that his paper failed of its full effect. Twenty years later, when Mitchell Banks advocated the routine removal of the axillary nodes in breast cancer, only one speaker was found to support his opinion. Gross, in 1888, from statistical studies, strongly supported Banks's views.

Is removal of the nodes in one piece with the primary growth essential to the success of the operation?—Gross, who was one of the first to advocate removal of the lymphatic nodes in carcinoma of the breast, used to pick them out from the axilla through a separate incision. Such a dissection was necessarily incomplete, and involved the division of possibly infected trunk lymphatics. To Halsted is due the adoption, in breast cancer, of the *monobloc* method of operation, though its desirability had been foreseen and advocated earlier by Moore.

Rationalization of the monobloc operation.—It is one thing to assert the desirability of the monobloc operation, it is another and a much more difficult thing to practise it, for the surgeon has no ocular evidence of the microscopic extension of the growth. Until recent years no systematic study of the mode of spread of cancer had been undertaken, or, at any rate, there was no general conception of its mode of spread. The establishment on a sure basis of the permeation theory of dissemination enables rational methods of monobloc removal to be planned with a good prospect that they will attain their object, though much remains to be done in investigating the spread of primary cancer in the internal organs. No surgeon can deal properly with cancer who has not made a study of lymphatic anatomy and its mode of spread.

The permeation theory was first worked out for breast cancer and for melanotic sarcoma. Accordingly, though it is applicable generally to carcinoma and to some sarcomata, its consideration is deferred to p. 665.

The object of the "monobloc" method, now usually accepted as desirable, is to ensure the removal of the trunk lymphatics connecting the primary focus with the lymph nodes that may be invaded.* If it could be shown that these trunk lymphatics are free from cancer-cells, then it would be safe to remove, first, the primary growth with the permeated area around it, and secondly, in a separate mass or by a

[illegible] onclude that the ideal

separate operation, the invaded nodes, remembering, however, that such a node may itself be a focus of permeation.

There is evidence that trunk lymphatics along which cancerous emboli have passed from smaller permeated lymphatics are not thereby invaded. The strong lymph-stream of these larger lymphatics scours them and transports to the nearest node all the cancer-cells which pass along them. As soon, however, as the entire catchment-area of a trunk lymphatic is choked by permeation of the small vessels which compose it, the lymph-current of the trunk lymphatic is arrested. Plugs of cells intruding into the trunk from permeated tributaries are no longer swept away. On the contrary, they continue to proliferate easily within its wide lumen, and the trunk lymphatic itself becomes permeated. Such permeated trunks may sometimes be felt in a late stage of breast cancer as nodular cords passing to the axilla. In rare cases the thoracic duct itself is in this way converted into a solid cord of growth.

The answer to the question whether monobloc removal of the nodes is indispensable evidently depends on the period of the disease at which trunk permeation begins. This probably varies according to the degree of cohesion between themselves possessed by the cancer-cells. If they cohere loosely, as in most cases of glandular cancer, trunk permeation will be deferred. If they cohere closely, as in squamous-celled carcinoma, the lymph-stream may fail to purge the trunk of the invading cylinder of cancer-cells, and trunk permeation begins. In most cases of breast cancer clinically regarded as operable, trunk permeation is still absent. On the other hand, in cancer of the lower lip, trunk permeation is certainly present in quite early cases; this is indicated by the frequency of recurrence at the apex of the V in V-shaped excisions. The same is probably true of the tongue.

On the whole, it may be concluded that, while monobloc removal of the growth and nodes is not in all cases essential, it is nevertheless most desirable in the absence of a dominant contra-indication.

If, as in cancer of the tongue, the primary growth is situated in a septic area which cannot be shut off, separate removal of the primary growth and of the nodes is usually the better practice. The risk of leaving permeated trunk lymphatics is outweighed by the more immediate risk of sepsis in a large cervical wound. The operator may legitimately hope in such cases that permeation of the trunks has not yet begun. He may also rightly urge, as Jamieson and Dobson pointed out,* that it is really impracticable to remove, *even by a* monobloc dissection, all the trunk lymphatics running from a cancerous focus in the tongue.

In 70 cases of tongue cancer operated upon by Butlin—hardly any of them monobloc operations—there were 29 successes. These figures indicate either that in over 40 per cent. of operable cancers of the tongue there is no trunk permeation, or that in some cases the permeated trunks remaining after operation are destroyed by inflammatory

* *Brit Journ. Surg*, July, 1920, vol. 80.

reaction or otherwise. They afford no reason for impugning the value of the general principle of monobloc operation, which is well established, and only to be violated for sound reasons such as are present in the case of lingual cancer. Apart from the reasons already urged in its favour, the monobloc method minimizes the risks of implantation.

Radiation-excision method.—The monobloc operation has of late ceased to be regarded as the standard method of dealing with many cancers, such as those of the tongue, mouth, lip and penis. The primary growth is most often dealt with by the implantation of radium or is destroyed by radiotherapy in some other form. The nodes are excised by a separate systematic operation. Regaud has found that radium treatment of the nodes in cancer of the tongue does not give adequate security against recurrences. To secure the best results the operation for removal of the nodes must be very complete and extensive, not confined to the removal of those nodes which are visibly or palpably enlarged but including clearance of the whole area.

This is no new doctrine; it was insisted upon by Butlin many years ago. If, in cancer of the tongue, only the enlarged nodes—say the tonsillar, submaxillary or submental groups—are removed, recurrence in the lower nodes of the main deep cervical chain is almost invariable.

It is not difficult to account for the unsatisfactory results of restricted operations. Briefly, infection of a node with cancer-cells occurs some time before there is any clinical evidence. Recurrence is nearly certain unless the apparently normal nodes adjoining the enlarged ones are removed. The ideal is complete removal of the nodes of the affected region. The task is no light one, and is impossible without a detailed working knowledge of lymphatic anatomy. The old rule of thumb that the nodes requiring removal are those which the operator finds enlarged must be abandoned. Along with it must go the idea that node operations can be dispensed with when there is no clinical evidence of nodal invasion.

Implantation of cancer during operation.—An important object of the monobloc operation is to prevent the setting free of cancer-cells in the wound. It is known that an animal suffering from spontaneous cancer can be readily inoculated with a fragment of its own growth. In France the experiment has actually been made with success on the human subject. It is evident, therefore, that if a cancer is cut into during removal a risk of accidental inoculation of the wound at once arises. The late Sir C Ryall ("Cancer Infection and Cancer Recurrence") drew special attention to this danger. He quotes several interesting cases. In one case a stitch-hole in the operation scar was the site of the recurrence. In a second case, where the clavicle was divided to reach invaded supraclavicular nodes, the wound healed but the bone became the site of recurrence. In a third case, an operation for a small tumour of the breast, the whole chest within two months of the operation was involved in cuirass cancer, in this case the

operator had used ... and for its subs ... of the neck may rapidly follow ... carcinomatous node during operation.

Ryall collected a series of 25 cases of implantation which had come under his observation. The most striking case I personally have seen was that of a lady upon whom a gastrectomy had been performed in America for carcinoma. The operation was completely successful. Some months later, when she was apparently in good health, a small solitary nodule appeared in the subcutaneous tissue of the operation scar. Soon it began to grow rapidly, but she postponed seeking advice and ultimately died with extensive infiltration of the abdominal wall.

Ryall held that, if it could be avoided, a doubtful tumour should not be cut into and excised at the same operation. The incision wound should be hermetically sealed, or allowed to heal, before the healthy tissues surrounding the tumour are excised. But if it is absolutely necessary to incise and to remove a malignant growth at the same sitting, the most elaborate precautions should be taken. The exploratory incision must be carefully sutured. The skin must be freshly prepared, the surgeon's and assistants' hands must be sterilized afresh, and every instrument, including the needles, must be reboiled; soiled towels and sponges must be discarded, and the operation begun anew.

Personally, I believe that if a carcinoma is incised it is safer to ablate it at once rather than to wait for the wound to heal. The circulatory activity and inflammatory processes of healing must, I think, tend to favour rapid dissemination. The incision should be packed with a swab dipped in pure carbolic acid and tightly sutured, and the operation of excision should be begun *de novo*, with the precautions detailed by Ryall. A pathologist skilled in the interpretation of frozen sections should always be present to make an immediate histological examination when a suspected lump is explored.*

At the end of every cancer operation, failing any contra-indication, the wound should be flushed out with a vigorous stream of fluid to wash away any loose cancer-cells I always use 1-in-2,000 perchloride-of-mercury solution, which will probably coagulate and destroy any isolated cancer-cell which is not washed away.

Radium in the prevention of implantation.—In any case where it is thought possible that cancer-cells have been set free in the wound during an operation, or where complete removal of the growth has proved impracticable, the most effective precaution which can be taken is to embed in the floor of the wound a sufficient number of radium needles effectively to radiate the suspected area. It is, for instance, not rare in operating upon the supraclavicular nodes for breast cancer, to find a fixed and irremovable mass at the angle of union of the internal jugular and subclavian veins Such a mass may

* A surgeon trained in naked eye pathology will seldom be in doubt as to the nature of a lump which he has incised If there is uncertainty it is just, in these circumstances, that the morbid histologist may hesitate to give an opinion on a frozen section Both surgeon and pathologist will, therefore, prefer to wait until paraffin sections can be prepared and examined without haste For the decision may entail the removal of an important organ or even the amputation of a limb (G Grey Turner)

be transfixed by a radium needle when exposed, but could not be treated effectively by blind methods.

In 1931, during an operation for recurrent nodes in tongue cancer in a man of 65, after the primary growth had been suppressed by radium, a degenerate node near the root of the neck ruptured and discharged its contents over the wound. The wound was washed out, first with perchloride of mercury, 1 in 1,000, to coagulate the albumin of isolated free cancer-cells, and then with saline to prevent the injurious action of mercury upon the platinum of the radium needles. About ten radium needles of 2 and 3 mg., well distributed, were left in the wound for a week. There was still in 1944 no recurrence, and the patient had become the father of an only son If the skin-flaps are thin, radium needles must not be left too close to their deep surface.

X-rays in the prevention of implantation.—A course of X-rays should always be applied, after healing, in a malignant growth which is susceptible to their action. Their value may be doubtful in refractory growths such as squamous-celled carcinoma. In other cases it may decide the success of the operation. Thus, for instance, it seems almost certain that a prophylactic course of X-rays would have prevented the development of the implantation nodule in the abdominal wall which proved ultimately fatal in the case of gastric carcinoma referred to above (p. 659).

Since the last edition of this work was published I have seen two other cases of implantation recurrence in the abdominal wall, one following the removal of a malignant ovarian tumour, the other the the removal of a carcinoma of the cæcum. In the first case buried radium treatment supplemented by X-rays suppressed the recurrence. In the second, radium failed and excision became necessary.

PATHOLOGY AS THE FOUNDATION OF CANCER SURGERY

Many surgeons, developing surgical methods of dealing with cancer, have largely trusted to a comparison of the results of various empirical operations. In this country the late Sir Harold Stiles was the first to perceive the necessity of founding operative procedure for cancer upon precise pathological studies. His researches on the anatomy of the breast and on the pathology of a hundred excised breasts led to the description by Cheyne and himself of a method superior to that of Halsted in its insistence upon the necessity for a wide removal of the circum-mammary fascia, and in its relative economy of skin. Stiles, however, failed to lay stress upon the routine removal of the lower half of the great pectoral, which was rightly demanded by Halsted.

Heidenhain and Stiles both emphasized the presence throughout the breast and upon the pectoral fascia of lymphatics plugged by cancer-cells, but their researches were confined to breasts removed by operation, and they failed in consequence to reach a general conception of the process of dissemination. Systematic histological researches on

post-mortem subjects led me, in 1904, to a view of the process of dissemination which is known as the permeation theory. Permeation appears to be the main agent of dissemination in all varieties of carcinoma and in some sarcomata, and it is as necessary for a surgeon to be familiar with the laws governing this process as for a hunter of game to understand the habits of his quarry.

The surgeon dealing with cancer cannot walk by sight, for the fringes of the disease are microscopic. He must be guided by mental conceptions of the invisible, and upon the accuracy of these conceptions his operative results will largely depend.

[illegible] the spread of cancer [illegible] strangely neglected [illegible] e lymphatic anatomy Sappey's great work on the lymphatic vessels, with its beautiful plates,



[illegible]

(Handley's "Genesis of Cancer," Second edition, 1935, John Murray, London, and Macmillan Co., New York.)

should be studied, supplemented by the standard work of Rouvière (*Anatomie des Lymphatiques de l'Homme*, Masson, 1932). Here I can give only the briefest anatomical outline, restricted to the parietal lymphatic system.

Lymphatics of the skin. (Figs. 270, 271.)—The lymphatics of the skin originate in the papillæ as blind end-sacs. By lymphatic injections of soluble Prussian blue I have been able to show that these end-sacs unite by groups to form less numerous vessels, which pierce the deeper layers of the dermis and the underlying subcutaneous fat, to discharge into the lymphatic plexus which lies upon the deep fascia.

Two cutaneous plexuses have been described—the subpapillary plexus of Sappey and the deep cutaneous plexus of Arnold. The skin appears to be divided into small lymphatic areas, each probably [illegible] y of the fascial plexus and [illegible] unite to form it. The size [illegible] estimate at from $\frac{1}{3}$ to $\frac{1}{2}$ in. in diameter, and there seems to be little communication between adjoining areas, except through the medium of the fascial plexus—a fact which explains the nodular character of cancerous invasion of the skin. Both the so-called cutaneous plexuses appear to be illusions.

There must, however, be some ground for the fact that these plexuses have been described, and it would appear that the superficial third of the dermis and the superficial layer of the subcutaneous fat are " planes of confluence "—layers, that is, in which groups of lymphatic vessels are running together to form single vessels. A plexiform appearance is thus produced in these layers, just as the tangle of branches in a wood might lead the observer to imagine that the branches of the trees were united in a plexiform arrangement.



Fig. 271.—A section vertical to the skin through the edge of an area of Paget's disease. The pattern of the cutaneous lymphatic vessels is emphasized and coarsened by their distension with malignant cells.

(Handley's " Genesis of Cancer ")

The independence of adjoining lymphatic areas of skin is a fact of great pathological importance. Its full appreciation will, I believe, throw light upon some of the obscurities of cutaneous pathology.

Besides the small tributaries which dip down vertically into the fascial plexus from the surface of the body, there are running upwards to the deep aspect of the fascial plexus numerous vessels by means of which it communicates with the lymphatics of the subjacent tissues. I have frequently observed such vessels passing to the deep fascia from the

muscles, and the special liability of some of the subcutaneous areas of the skeleton to cancer appears to show that the fascial plexus anastomoses in a similar way with the periosteal lymphatics wherever they approach the surface.

The lymphatics of the breast, though some of them run to the subareolar plexus, and thence to the axillary nodes, largely drain into

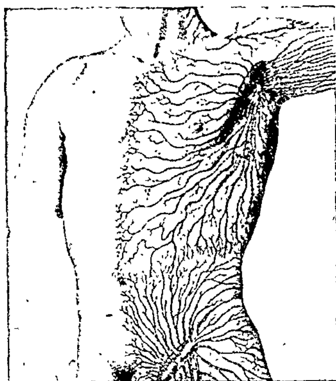


Fig. 272.—Trunks of fascial plexus.
The fine meshwork of vessels constituting the plexus itself is only partially indicated.
(*After Sappey's "Vaisseaux Lymphatiques."*)

the pectoral plexus, that part of the deep fascial lymphatic plexus which lies behind the breast.

The fascial lymphatic plexus.—The lymphatic plexus of the pectoral fascia is often spoken of as if it were an anatomical entity. It is, in reality, merely a conventional subdivision of the deep fascial lymphatic plexus whose network of intercommunicating channels invests the entire body. This plexus (Fig. 272) is divisible by the median plane of the body, and by two horizontal planes passing through the clavicles and through the umbilicus respectively, into six catchment areas, three on either side, draining, as the case may be, into the cervical, the axillary, or the inguinal nodes. Within each area a special set of trunk lymphatics arises from the plexus and converges on the corresponding set of nodes. The line, or rather zone, separating any two adjacent areas may be called the lymphatic water-parting, and is anatomically a zone of narrow, tortuous channels,

There must, however, be some ground for the fact that these plexuses have been described, and it would appear that the superficial third of the dermis and the superficial layer of the subcutaneous fat are " planes of confluence "—layers, that is, in which groups of lymphatic vessels are running together to form single vessels. A plexiform appearance is thus produced in these layers, just as the tangle of branches in a wood might lead the observer to imagine that the branches of the trees were united in a plexiform arrangement.



Fig. 271.—A section vertical to the skin through the edge of an area of Paget's disease. The pattern of the cutaneous lymphatic vessels is emphasized and coarsened by their distension with malignant cells.

(Handley's " Genesis of Cancer ")

The independence of adjoining lymphatic areas of skin is a fact of great pathological importance. Its full appreciation will, I believe, throw light upon some of the obscurities of cutaneous pathology.

Besides the small tributaries which dip down vertically into the fascial plexus from the surface of the body, there are running upwards to the deep aspect of the fascial plexus numerous vessels by means of which it communicates with the lymphatics of the subjacent tissues. I have frequently observed such vessels passing to the deep fascia from the

muscles, and the special liability of some of the subcutaneous areas of the skeleton to cancer appears to show that the fascial plexus anastomoses in a similar way with the periosteal lymphatics wherever they approach the surface.

The lymphatics of the breast, though some of them run to the subareolar plexus, and thence to the axillary nodes, largely drain into

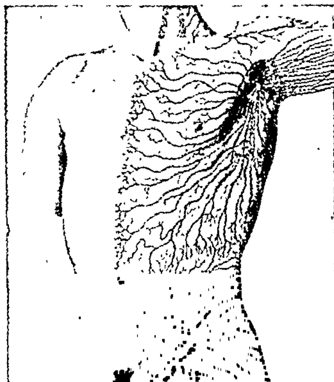


Fig. 272.—Trunks of fascial plexus.
The fine meshwork of vessels constituting the plexus itself is only partially indicated.
(After Sappey's "Vaisseaux Lymphatiques")

the pectoral plexus, that part of the deep fascial lymphatic plexus which lies behind the breast.

The fascial lymphatic plexus.—The lymphatic plexus of the pectoral fascia is often spoken of as if it were an anatomical entity. It is, in reality, merely a conventional subdivision of the deep fascial lymphatic plexus whose network of intercommunicating channels invests the entire body. This plexus (Fig. 272) is divisible by the median plane of the body, and by two horizontal planes passing through the clavicles and through the umbilicus respectively, into six catchment areas, three on either side, draining, as the case may be, into the cervical, the axillary, or the inguinal nodes. Within each area a special set of trunk lymphatics arises from the plexus and converges on the corresponding set of nodes. The line, or rather zone, separating any two adjacent areas may be called the lymphatic water-parting, and is anatomically a zone of narrow, tortuous channels,

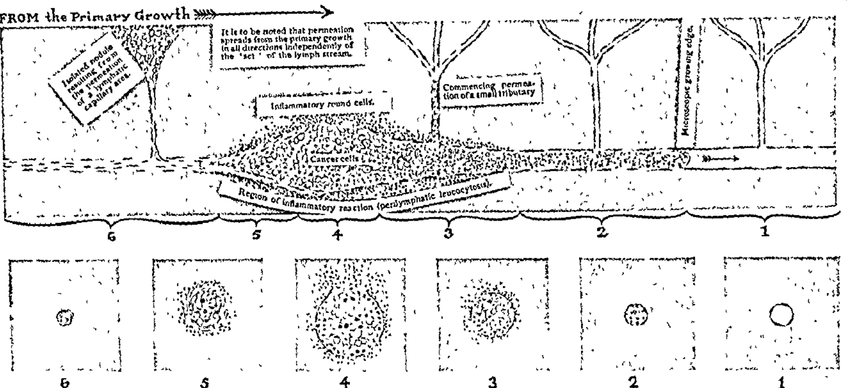


Fig. 273.—Scheme to illustrate advance of permeation along a small lymphatic, seen in the upper figure in longitudinal section, and in the lower figures as a series of transverse sections. The lymphatic is finally destroyed by perilymphatic fibrosis. (*Handley's "Cancer of the Breast."*)

1. Normal lymphatic, shortly to be invaded by the advance along it of permeation. 2. The lymphatic permeated by cancer-cells, but not yet distended. (Note the absence of inflammatory reaction in this region.) 3. The lymphatic distended by the growing cancer-cells; the central cancer-cells are becoming degenerate. 4. The lymphatic ruptured by the growing cancer-cells, an event followed by vigorous inflammatory reaction. 5. The mass of degenerate cancer-cells enclosed in a false capsule of newly-formed fibrous tissue. 6. The cancer-cells finally strangled by contraction of their fibrous capsule. The original lymphatic is now represented simply by a thread of fibrous tissue, the cancer-cells having been destroyed, but meantime permeation has continued to spread further afield.

nowhere traversed by trunk lymphatics—a region, consequently, where the lymph-stream is at its feeblest, and where even very fine particles are likely to be arrested. The general idea, then, of the parietal lymphatic system is a vast horizontal network of fine channels, co-extensive with the surface of the body, and receiving above numberless fine vertical tributaries, which convey to it the lymph from the skin and its appendages, including the breast. On its deep aspect the plexus receives tributaries from the subjacent tissues. From this great plexus, which lies in the subcutaneous fat upon the deep fascia, the lymph is conveyed by six sets of lymphatic trunks, each draining a definite area, to the cervical, the axillary, or the inguinal nodes.



Fig. 274.—Infiltration in breast cancer, showing narrow columns of cancer-cells growing along the cellular interspaces. x 20 (Cf. Fig. 275)

The Permeation Theory of Dissemination

Permeation may be defined as the choking-up of lymphatic vessels by the growth of cancer-cells along them. The lymph-stream has nothing to do with it. The proliferative power of cancer-cells is so great that when they intrude into a lymphatic capillary they advance along it, either with or against the stream, as a solid plug or growing tendril of cancer-cells. (Fig. 273.) Only in the trunk lymphatics will the intrusive cancer-cells be swept away by the stream to form an embolus in the nearest nodes.

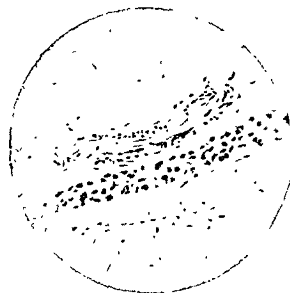


Fig. 275.—Permeated lymphatic in longitudinal section. x 50 (Cf. Fig 274)

Some recent writers have used the word "permeation" as synonymous with "infiltration". It will be well, therefore, to state clearly, in tabular form, the differences between those two modes of spread of carcinoma.

Infiltration (Fig. 274)	Permeation (Fig. 275)
The earliest disseminative process.	Begins later than infiltration.
Best seen at the edge of the primary growth, as defined by the naked eye.	Best seen at the *microscopic growing edge*, which, in advanced cases, may be situated in apparently normal tissues, 6 in. or more from the apparent edge.
The cancer-cells are spreading along the tissue interspaces, e.g. between fat-cells, or between adjoining fibrous bundles.	The smaller lymphatic vessels are filled up and choked by solid cords of cancer-cells. The tissue interspaces are free from cancer-cells.
If infiltrating cancer-cells intrude into a capillary lymphatic vessel, the process of infiltration merges into that of permeation.	If a permeated lymphatic ruptures, the cancer-cells set free may infiltrate the surrounding tissues. Thus permeation may lead to infiltration.
Infiltration is a very slow process because of the resistance offered to the passage of cancer-cells through the cramped and tortuous tissue interspaces.	Permeation is a more rapid process than infiltration, because the cancer-cells are growing with little resistance along the open lumen of the lymphatic vessels.
Infiltration, on account of its slowness, is of relative unimportance as a factor in general dissemination.	Permeation may carry cancer-cells to a very considerable distance from the primary tumour, and is capable of traversing the minute anastomotic lymphatic plexuses. It is accordingly the principal factor in general dissemination.

A close analogy exists between the process of permeation and the artificial filling-up of the lymphatic channels by an injection fluid such as is used by anatomists to demonstrate the lymphatic vessels. If a hollow needle connected with a reservoir containing soluble Prussian-blue solution is plunged into the breast, the fluid will enter the lymphatic vessels near the point of the needle and, after filling up the internal lymphatics of the breast for some distance around the point of injection, will pass backwards along certain lymphatic vessels, first demonstrated by Heidenhain, to the lymphatic network on the great pectoral muscle. This pectoral lymphatic plexus is a portion of the great fascial lymphatic plexus, which forms a single network lying on the deep fascia and covering the entire body. The injection fluid will spread along this network centrifugally, involving a continually increasing circular area of the fascial plexus. The centre of the injected area will always be situated directly beneath the point of introduction of the needle into the breast Its circumference may easily pass far beyond the mammary margin.

The fascial lymphatic plexus receives minute tributaries from the muscles beneath and from the skin above At first it will be easier for the fluid to keep in the plane of the main plexus, and these little tributaries will escape injection. But, as the area of the injection circle

increase [illegible]
ance. [illegible]
of the fascial plexus, and injected areas will appear in the skin and subcutaneous tissues on the one hand, and in the underlying muscles on the other. At the periphery of the circle of injection, on the contrary, the fluid will find it easier to keep along the main plexus, rather than to push up the narrow side-channels. Here, accordingly, no injection will be seen, except in the plane of the main fascial plexus.

The fascial plexus is drained by certain trunk lymphatics which pass to the cervical, the axillary, or the inguinal nodes. The axillary trunks will soon be filled up by the injection as far as the nodes.

The spread of cancer of the breast, or of a cutaneous melanotic sarcoma, from the primary growth is exactly analogous to that of an injection fluid save in one respect. Any cancer-cells which intrude into a trunk lymphatic will be swept by the lymph-stream to the nearest nodes, and the trunk lymphatics themselves will thus be scoured and kept free from cancer-cells. Only in a later stage of the disease are the trunk lymphatics choked by permeation.

Observations upon which the permeation theory is based.—Although in 1889 Heidenhain detected lymphatics filled by cancer-cells extending from the breast to the pectoral fascia in two-thirds of the cancerous breasts he examined, this important observation remained isolated, and failed to affect the general view of dissemination, even in the mind of Heidenhain himself. M. B. Schmidt has proved that cancer-cells frequently reach the blood-stream, but it appears certain that in nearly all cases these cells are then destroyed, for I have shown that the distribution of the secondary deposits is not such as would be expected from this mode of dissemination. The evidence cannot be fully stated here, but its salient features are as follows. The secondary deposits accessible to observation in breast cancer appear at first near the primary growth, and spread from it centrifugally, involving a continually increasing circular area of the tissues round the growth, but never encroaching upon the distal half of the limbs, the parts which, upon the embolic theory, would appear most liable to metastases. The freedom of the distal portion of the limbs applies not only to subcutaneous nodules but also to deposits in the bones.

I have endeavoured to elucidate this process of centrifugal spread by cutting long sections of the tissues radiating from a primary growth of the breast into parts of the body still unaffected. In the proximal portion of the strip—the parts, that is to say, nearest to the primary growth—I found large isolated nodules of growth. Further out, in tissues apparently healthy to the naked eye, and perhaps 6 or 8 in. from the primary growth, I detected what I have described as the *microscopic growing edge* of the disease. This edge could be reached in whatever direction the section was orientated from the primary growth itself. It forms a narrow zone, a few millimetres wide, in which all the vessels of the lymphatic plexus that receives the drainage of the cancerous organ are choked by cancer-cells. The detection

of the real microscopic growing edge of a cancer forms the unshakable foundation of the permeation theory. The grave difficulty remained that in the region nearer the primary growth no permeated lymphatics could be found. This difficulty was solved by the detection of the curative process of *perilymphatic fibrosis*. A permeated lymphatic is not a permanent structure. The inflammatory reaction excited around the invaded lymphatic by the presence of cancer-cells within it strangles the minute cord of cancer-cells, and the original vessel is replaced by a microscopic cord of fibrous tissue. (Fig. 278.)

Here and there, however, the reparative process fails, and at these points within the circle of permeation nodular deposits of cancer form. These isolated secondary nodules have really arisen in continuity with the primary growth and in the track of the spreading circle of permeation. Their isolation is a secondary phenomenon due to the destruction by perilymphatic fibrosis of the permeated lymphatics which formed the lines of communication.

The permeation theory probably applies to every form of carcinoma, and also to melanotic sarcoma. It has been confirmed in breast cancer by Bonney, Rowntree, and others. Lenthal Cheatle has observed permeation in carcinoma of the tongue, and I have demonstrated it in cancer of the rectum and of the stomach.

Visceral dissemination.—A cancer, even if it originates in the superficial structures, such as the skin or breast, often ultimately destroys life by invading the vital organs. Sooner or later, it may be after many years, permeation extends from the superficial lymphatics to the subserous lymphatics of the pleura or the peritoneum, an event which soon leads to the escape of cancer-cells into the serous cavities. The malignant cells, under the influence of gravity and visceral movement, spread widely in the serous cavity invaded, and implant themselves afresh on the serous surfaces of the viscera, in which cancerous masses appear, and within a few months the patient succumbs. A very interesting example of serous invasion followed by this process of transcœlomic implantation is often seen in breast cancer.

Epigastric invasion in breast cancer.—At the tip of the ensiform cartilage the fascial lymphatic plexus is separated from the subperitoneal lymphatic plexus only by a layer of fibrous tissue, the linea alba, and by loose subserous fat. At or near this point, which is situated only an inch from the margin of the breast, breast cancer often directly invades the abdomen. The linea alba is infiltrated by cancer-cells from the overlying permeated fascial plexus. These cells reach the subserous fat, permeate the subserous lymphatic plexus, and escape into the peritoneal cavity, where they implant themselves on the contiguous convex surface of the liver. Other cells are carried by gravity into the pelvis, where they attack the ovaries and the pelvic peritoneum. Thus extensive secondary deposits may form in the abdomen before the thoracic cavity shows any sign of secondary deposit. (Handley, Astley Cooper Prize Essay, 1904.)

Invasion of the peritoneum in breast cancer is now much rarer than

formerly. Removal of the upper part of the anterior layer of the rectus sheath is now a recognized step of the operation for breast cancer, and direct invasion below the ensiform cartilage is thus prevented.

Main processes concerned in dissemination.—The processes concerned in dissemination are infiltration, permeation, lymphatic embolism leading to deposits in the lymphatic nodes, transcœlomic implantation, and, in exceptional cases, blood dissemination by embolism, or by the growth of solid plugs of cancer-cells along the blood-vessels.

Infiltration has only a local importance, but permeation, which can extend without let or hindrance throughout the lymph-vascular system, is the main factor in dissemination.

Blood-dissemination.—Of late, owing to the undue stress laid on blood-dissemination in R. A. Willis's work, " The Spread of Tumours in the Human Body " (Churchill, 1934), there has been a certain sway of opinion back to the old embolic theory. But Willis, though he was specially looking for evidence of blood-borne metastasis, appears to have found it in about only 36 per cent. of his cases. There is, of course, no doubt that cancer-cells obtaining access to the blood-stream may cause remote secondary deposits. There is equally no doubt that many such emboli are destroyed without causing metastasis (Schmidt). Willis draws attention to the small size of many of the embolic secondary nodules he detected, but does not draw the natural inference that *successful* invasion by the blood-stream occurred only a short time before death. The lateness, and consequent surgical unimportance, of blood-dissemination is further shown by the favourable results of operation for breast cancer in really early cases, before invasion of the axillary nodes. Blood-dissemination in carcinoma, though in rare cases it may occur early, is usually an ante-mortem event. Otherwise surgical removal would be futile.

THE AIM OF THE OPERATION FOR MALIGNANT DISEASE

It has been customary to speak of operations for cancer in terms of the removal of organs. Thus the operation for breast cancer is often called an amputation of the breast. This looseness of speech encourages unscientific operations It implies, for example, that a single standard operation is applicable to all carcinomata of the breast, in whatever part of the breast they originate. Some surgeons who have described modes of operation for breast cancer make no attempt to vary their procedure according to the point of origin of the growth.

It is wrong to speak of a cancer operation as an operation for the removal of an organ, because carcinoma spreads from its point of origin centrifugally, with little regard to the boundaries of organs. A carcinoma starting on the edge of the breast will soon have spread

beyond the limits of the breast on that side. If it is treated by an "amputation" rapid local recurrence will take place where the knife, following the outline of the breast, had failed to get beyond the growth.

In general terms, the object of a rational operation for carcinoma (and for melanotic sarcoma) is *the removal intact of the permeated area of the lymph-vascular system which surrounds the primary growth, and of the lymphatic nodes which have been embolically invaded along the trunk lymphatics of the area concerned.*

The surgery of malignant disease is a department of lymphatic surgery, and has nothing to do with the ablational surgery of organs.

1. **The operation must be accurately centred upon the primary growth.**—If cancer spreads by centrifugal permeation with approximate equality in all directions, but with a tendency to follow the plane in which the main lymphatic plexus lies, it is essential that the primary growth shall always be the central point of the mass of tissues ablated.

2. **The plane requiring the widest removal is that in which the microscopic growing-edge is situated**—the plane, that is, in which is situated the lymphatic plexus receiving the lymphatic drainage of the cancerous part

In malignant growths of the superficial tissues, the skin and its appendages (among which the breast is included), the plane of maximal removal is the plane of the deep fascia. To make reasonably certain of getting beyond the microscopic growing edge in an average case of breast cancer, I estimate for the removal of a circle of deep fascia 10 or 12 in. in diameter, and centred upon the primary growth. Since far less skin needs removal, the skin-flaps must be extensively undermined.

3. **Planes adjacent to the plane of the main lymphatic plexus require to be ablated over a certain area concentrically with the growth but less widely than the plane of the growing edge.**—The planes to be considered are (*a*) the skin and subcutaneous fat; (*b*) the muscles underlying the deep fascia. The reason they are infected is that their lymphatics drain into, or communicate with, the fascial lymphatic plexus, from which permeation extends to them. The reason they are invaded over an area smaller than the circle of the growing edge in the deep fascia is that the cancer-cells for some time find it easier to proliferate in the meshes of the main plexus than to fill up the narrow side-tracks which run into it.

(*a*) **Ablation of skin.**—When cancer nodules appear in the skin near a breast cancer, they spread centrifugally away from the primary growth. This has been erroneously taken to prove that the disease spreads in the plane of the skin. In this belief some operators have sacrificed such extensive areas of skin that they have to resort habitually to skin-grafting. The curious thing was that skin nodules continued to appear beyond the extensive area of skin removed. The attention concentrated upon the skin was diverted from the deep fascia in which the unrecognized microscopic growing edge lay

concealed, ready to effloresce later in the form of skin nodules as permeation extended to the skin at isolated points.

In breast cancer, I have shown conclusively that removal of a circle of skin 4 or 5 in. in diameter centred upon the primary growth is sufficient in nearly all cases to prevent recurrent skin nodules, *provided that the microscopic growing edge is ablated* by a wide removal of the deep fascia. This conclusion, arrived at by histological work in the laboratory, has been amply confirmed by clinical experience. The history of this subject is an excellent example of the value of pathological research in checking operative excesses.

(*b*) **Removal of muscle.**—The need to remove a layer of muscle subjacent to the primary growth depends on the extension of permeation from the fascial lymphatic plexus into its muscular tributaries. As far as possible, the layer of muscle removed should attain its maximum thickness just beneath the primary growth, and should become thinner towards the periphery of the operation area. But for several reasons ablation of muscle cannot be carried out in the same strict conformity with the law of centrifugal spread as is possible and desirable with the skin and deep fascia. For, in the first place, once a muscle is invaded by cancer, its contractions probably lead to a wide dispersion of cancer-cells in the direction of its fibres between the muscular bundles, so that the whole muscle must be regarded as suspect. In the second place, it is useless to scoop out a circular portion of muscle on the centrifugal principle, because the remaining portions will be functionally useless and may become a cicatrix hampering the movements of adjacent joints.

The present practice in removing muscles appears to be correct. In breast cancer originating in the upper part of the breast the whole of the great pectoral, and in other cases the whole of the muscle except its clavicular fibres, should be removed, as Halsted recommends. The removal of this muscle is essential, not only on account of its close relations with the breast, but also in order to reach the apex of the axilla. The minor pectoral, which is in direct contact with the breast along its lower border, should also be taken away. Furthermore, it is important to remove the fascia over the digitations of the serratus magnus, which lie in direct contact with the deep surface of the breast, also from the digitations of the external oblique, which arise from the 5th and 6th ribs, for a similar reason.

An outstanding service of Halsted to breast surgery is that in every case he insisted on the removal of the sternal portion of the great pectoral. This step found many opponents, who asserted that it produced serious disability. As late as 1909 the weight of French surgical opinion was opposed to ablation of the pectoral. As a matter of fact, if the after-treatment is properly conducted, the disability is negligible.

Speese has ended controversy by a paper recording the examination of the great pectoral in 100 consecutive cases. The muscle, or the

pectoral fascia in contact with it, showed cancer in 37 cases. In 5 cases in which the growth was free from adhesion to the muscle there were, nevertheless, metastases in the muscle.

General considerations in the removal of lymphatic nodes.—The systematic removal of possibly infected lymphatic nodes is imperative in all malignant tumours, except those which are definitely known not to disseminate by the lymphatic system. The exceptions include rodent ulcer, many of the less malignant sarcomata, and carcinomata arising at points where an extensive area of the lymphatic system has previously been destroyed by a lymphangitis. Of the last class, epithelioma arising on a large scarred area of lupus may be taken as a type.

It has been commonly believed that the sarcomata do not disseminate by the lymphatic system. I have proved that this is quite erroneous in melanotic sarcoma; it is probably untrue of many other sarcomata. Therefore, except in the fibro-sarcomata, removal of the nodes should be the rule. It should never be omitted in sarcoma of the tongue, the testis, or the tonsil, in periosteal sarcoma or in sarcoma of the breast.

In general terms, the nodes requiring removal are those which receive the lymphatic vessels of the area where the malignant growth arises. The task is not so simple as it seems. In the first place, afferent lymphatics may pass by the first set of nodes they reach and may run directly to the set above. Thus, lymphatic vessels often run directly from the breast to the highest axillary nodes, and these may be cancerous when the lower axillary nodes are still free. Again, in the tongue, as Jamieson and Dobson have shown, some of the lymphatic vessels may pass directly to the lower deep cervical nodes instead of entering the upper deep cervical nodes. Moreover, every infected node is itself a centre of infection for those farther off. It is true that for a long time a node filters off the cancer-cells which reach it; but sooner or later the growth permeates to its efferent lymphatics which are afferent to the nodes higher up. In this way the supraclavicular nodes are often reached in breast cancer, or the iliac nodes when there are secondarily invaded inguinal nodes.

It must not be forgotten that in its early stages node infection is a microscopic and clinically inappreciable process. Accordingly, the fact that no enlarged nodes can be felt does not absolve the surgeon from the duty of performing a complete node dissection if the growth is one which habitually disseminates by lymphatic channels. Only in very old and feeble patients can a relaxation of this rule be allowed, and its neglect is a frequent cause of failure.

A primary growth may, by infiltration or permeation, reach an area which has a different lymphatic drainage from the area in which it originated Hence a knowledge of the respective catchment areas of the different sets of lymphatic nodes is very important. Thus, in a late stage of breast cancer, when the disease has permeated across the middle line, the opposite axillary nodes receive cancerous emboli along

their trunk lymphatics. Their enlargement indicates that permeation has crossed the middle line into their catchment area.

If a growth originates in or near the middle line, two sets of nodes will require removal—those of the two contiguous areas concerned. If a growth originates at the level of the umbilicus some way from the middle line, both the axillary and the inguinal nodes on that side must be removed. If a growth originates at the umbilicus itself, then if possible four sets of nodes should be excised—those in both axillæ and both groins.

If a growth originates just above the level of the umbilicus away from the middle line, removal of the axillary nodes on the affected side will suffice if the growth is early, but, if it has already infiltrated or permeated down to the level of the umbilicus, then, in addition, the inguinal nodes of the affected side must be removed.

Decussation of lymphatics.—The removal of nodes is complicated by the fact that lymphatic trunks originating on one side of the body may be afferent to nodes situated on the opposite side. The decussation of lymphatic trunks across the middle line is especially rich in the tongue, and Jamieson and Dobson have shown that the only portion of the tongue which discharges exclusively into nodes of the same side is the posterior two-thirds of the lateral margin. Accordingly, only in cancer of the lateral margin of the tongue is it reasonably safe to restrict node removal to those of the same side.

Comitance of lymphatics and blood-vessels.—Lymphatics and blood-vessels run in parallel and closely contiguous courses. Each small artery and vein is usually accompanied by two lymphatic vessels. If the latter become permeated, their rupture may be followed by infiltration of the wall of the comitant vein. The growth may thus in a late stage obtain access to the blood-stream, as I have demonstrated in melanotic sarcoma.

It is difficult to pursue the subject of this chapter into detail without trenching upon the province of those who have dealt with the surgery of cancer of the various organs. There are, however, two varieties of malignant growth which have no definite anatomical location. On that account they are usually passed over in works on operative surgery; and, as a natural sequence, their operative treatment is often very inadequate. These are rodent ulcer and malignant melanoma of the skin. Their consideration will illustrate the principles governing the operative treatment of (1) a malignant growth which has no tendency to disseminate; (2) a malignant growth which disseminates by permeation of the lymphatic system as well as by the blood stream.

(1) OPERATIVE TREATMENT OF RODENT ULCER
(Basal Celled Carcinoma)

Rodent carcinoma, or rodent ulcer, presents certain peculiarities which place it, as regards treatment, in a class apart from most malignant tumours. Chief among these peculiarities is the fact that



Fig. 276.—Very advanced rodent ulcer.

Beginning just in front of the ear, the ulcer has destroyed the pinna, entered the external auditory meatus, and infiltrated the bones of the skull, especially the temporal, which was exposed in the floor of the ulcer. Protracted X-ray treatment had proved useless. The swelling was due to accompanying inflammation and œdema.

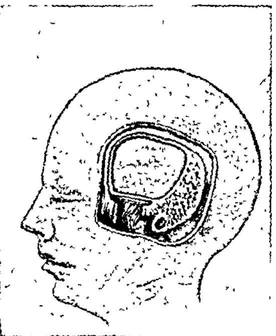


Fig. 277.—After block-removal of ulcer and subjacent infiltrated bone.

The dura mater is freely exposed in the squamous region of the temporal bone. The bone removal extends to the mastoid region, and cuts across the bony meatus and the temporo-mandibular joint. The zygoma has gone, and most of the temporal muscle. The external pterygoid and a few divided fibres of the temporal muscle are seen. The condition of the patient did not admit of a plastic operation or of skin grafting.



Fig. 278.—Later stage.

The wound has completely healed. The dura mater could still be seen pulsating under its thin covering of skin. The patient's general condition was greatly improved. The drawing was made shortly after the patient's discharge from hospital.

it does not disseminate, and that consequently ablation of the primary tumour is the surgeon's sole object. This alone, however, is often a business demanding all his resolution, for he is frequently called upon to operate in a late stage, either because the patient has not previously sought treatment, or because attempts to cure the disease by radiotherapy have not been effective.

The choice between radiation and operation.—While some rodent ulcers yield rapidly and completely to either X-rays *or radium*,



Fig. 279.—Advanced case of rodent ulcer treated unsuccessfully by radiation.

The eye had been destroyed, and the growth extended back into the orbit. The dotted line indicates the skin incision. The two following figures show the operation.

others prove refractory, or relapse after a period of apparent cure, and there is no means of telling beforehand which of these events will happen. To counterbalance its uncertainty, treatment by radiation possesses the advantages that it avoids an operation, and that the scar is often inconspicuous. In my opinion, operation should be preferred to or substituted for radiation in the following classes of rodent ulcer.

(*a*) *Where the disease is a small incipient plaque in which ulceration has hardly begun.*—The operation is a trivial affair, leaving a small linear scar. It is true that in most cases the application of radium



Fig 276.—Very advanced rodent ulcer.

Beginning just in front of the ear, the ulcer has destroyed the pinna, entered the external auditory meatus, and infiltrated the bones of the skull, especially the temporal, which was exposed in the floor of the ulcer Protracted X-ray treatment had proved useless The swelling was due to accompanying inflammation and œdema.

Fig. 277.—After block-removal of ulcer and subjacent infiltrated bone.

The dura mater is freely exposed in the squamous region of the temporal bone. The bone removal extends to the mastoid region, and cuts across the bony meatus and the temporo-mandibular joint The zygoma has gone, and most of the temporal muscle. The external pterygoid and a few divided fibres of the temporal muscle are seen The condition of the patient did not admit of a plastic operation or of skin grafting.



Fig. 278.—Later stage.

The wound has completely healed The dura mater could still be seen pulsating under its thin covering of skin The patient's general condition was greatly improved The drawing was made shortly after the patient's discharge from hospital

it does not disseminate, and that consequently ablation of the primary tumour is the surgeon's sole object. This alone, however, is often a business demanding all his resolution, for he is frequently called upon to operate in a late stage, either because the patient has not previously sought treatment, or because attempts to cure the disease by radiotherapy have not been effective.

The choice between radiation and operation.—While some rodent ulcers yield rapidly and completely to either X-rays or radium,



Fig. 279.—Advanced case of rodent ulcer treated unsuccessfully by radiation.

The eye had been destroyed, and the growth extended back into the orbit. The dotted line indicates the skin incision. The two following figures show the operation.

others prove refractory, or relapse after a period of apparent cure, and there is no means of telling beforehand which of these events will happen. To counterbalance its uncertainty, treatment by radiation possesses the advantages that it avoids an operation, and that the scar is often inconspicuous. In my opinion, operation should be preferred to or substituted for radiation in the following classes of rodent ulcer.

(*a*) *Where the disease is a small incipient plaque in which ulceration has hardly begun.*—The operation is a trivial affair, leaving a small linear scar. It is true that in most cases the application of radium

for a few hours will produce complete cure, but the dread of local recurrence is more surely excluded by operation.

(*b*) *Where the disease has recurred after apparently complete cure by radiation.*—An exception may perhaps be made in those cases where an operation involves serious disability or an especially disfiguring scar, but in the surgery of malignant disease an ugly scar or the loss of an eye may be the price of ultimate success.

(*c*) *Where the disease remains active at the end of three months from*

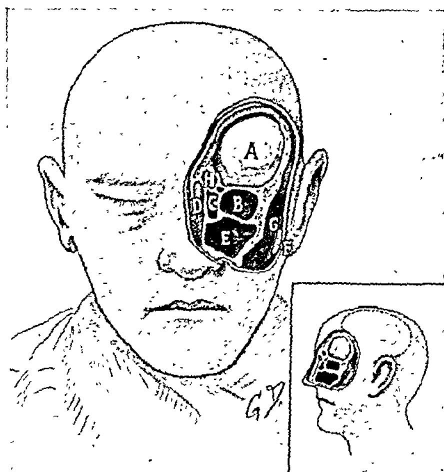


Fig. 280.—Same case as Fig. 279, after block-removal of affected parts, including portions of frontal, nasal, lacrymal, and ethmoid bones, and superior maxilla.

A. Frontal dura mater. B. Remains of orbit. C. Ethmoidal cells. D. Intact mucosa of nasal cavity. E. Maxillary antrum. F. Zygoma. G. Temporal muscle. The inset figure shows the scalp-flap which was utilized to fill up the facial gap.

the time radiation treatment began.—The type of rodent ulcer which responds sluggishly to radium or X-rays appears to be especially liable to relapse, even if complete cicatrization is at length obtained.

(*d*) *In cases where the ulcer has exposed a bone, has attacked cartilage or the conjunctiva, or has eaten deeply into soft tissues.*—Rarely, if ever, is radiation successful when once the disease has attacked a bone or has affected the conjunctiva.

The failure of radiotherapy to deal with rodent ulcer of the conjunctiva may be ascribed to several causes. The dosage has to be modified by consideration for the safety of the eye. The conjunctiva is closely related to the lacrymal bone and the anterior ethmoidal cells. If the disease attacks the conjunctiva near the inner canthus, the usual event, the disease probably attacks the ethmoid at about the same



Fig. 281.—Same case as Fig. 279, after healing had taken place.

time. In this bone it spreads rapidly and secretly, extending far back along the inner wall of the orbit without giving external manifestations of its presence. In such a case, removal of the eye is a necessary preliminary to treatment of the ethmoidal extension of the disease, and the orbital fat after removal is often found to be invaded.

Principles of operative treatment.—Rodent ulcer is one of the few forms of malignant growth where the primitive method of cancer surgery—the cutting out of the primary lump with a margin of healthy tissue—is still the method of choice. Every infirmary contains an example of the dreadful ultimate fate of some of the victims of this disease—the conversion of the face into a gaping chasm. The recollection of such cases brings the conviction that, even when operation involves the sacrifice of an eye, or the removal of part of the

frontal bone, the nasal bones or the maxilla, the patient should be earnestly advised to submit to the ordeal.

The method in these advanced cases is brutally simple, and may be described as a block dissection including bone, remorselessly pursued without regard to anatomical considerations. It is not generally realized how safely wide ablations of this kind can be made in face and



Fig. 282.—Rodent ulcer befo

forehead. Many cases of rodent ulcer a
could be cured or relieved for some year
The ulcer is surrounded at a distance o
margin by a ring incision which extends
incision a chisel is introduced, and wi
groove is cut in the underlying bone or
of my own, may perhaps have to tra
nasal bones, the superior maxilla, and
be introduced beneath the mass thus o
of mallet-blows and judicious leve
connections. It is very undesirable t

mouth, or the frontal sinus, if this can be avoided. Even when the overlying bones are involved, if care be exercised they can be stripped from the underlying mucosa without injury to the latter. If the whole thickness of the frontal bone has to be removed, special care should be taken to avoid septic infection of the exposed dura mater.

Hæmorrhage may be troublesome, but the parts are so freely exposed that it is unlikely to be dangerous. If, after tying off spurting vessels and applying Horsley's wax, there is still persistent free oozing,



Fig. 283 —Same case as Fig. 282, after excision.

the cavity may be packed with antiseptic gauze or absorbable gauze wrung out of 1-in-1,000 flavine, and the plastic part of the operation deferred. In cases where the nasal cavity may be opened during the operation, the nostril on the affected side should be previously plugged with gauze.

Plastic repair of the gap.—By the use of scalp- or neck-flaps, combined if necessary with transplantation of costal cartilage, the majority of extensive gaps in the face can be satisfactorily repaired. In this respect war experience has come to the aid of civil surgery. Even if the strain of an extensive plastic operation cannot be borne, it is surprising how much natural cicatrization will reduce the size and unsightliness of the defect. In any event, there are few defects which defeat the plastic surgeon of to-day.

Illustrative case.—The patient, aged about 55, had for sixteen years

with the superjacent growth, the shrunken eyeball and fatty contents of the orbit. The ablated mass contained most of the maxilla, without its alveolar border and posterior margin, a portion of the right malar, ethmoid, and inferior turbinate bones, the right lacrymal, both nasal bones and portions of the nasal cartilages. Bleeding was troublesome.

The cavity left after removal of the mass presented at the bottom a circular bony cell, the posterior third of the antrum of Highmore.

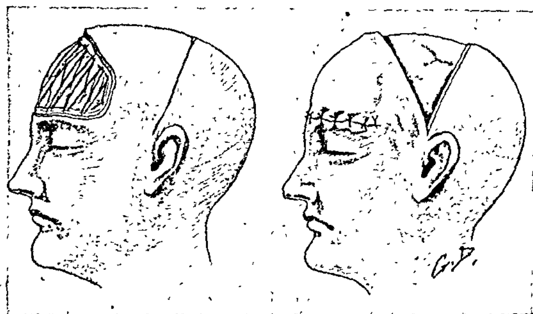


Fig. 287.—Same case, showing closure of frontal gap by bridge-flap.

On the inner side was the nasal septum, and above was the posterior part of the orbit. The lacrymal gland was included in the excised tissue. A large flap, with a pedicle below, was now marked out on the side of the cranium and was raised from the epicranial aponeurosis and brought forward to cover the gaping chasm. The denuded area of scalp was at once grafted from the skin of the thigh The patient seemed little the worse for this severe operation, and made a rapid and apyrexial recovery, with very great improvement in his general health and appearance (Fig. 283)

In 1921, three years after the operation, the disease recurred about the right nostril, in the region where the operation was restricted in order to avoid opening the mouth cavity. Here a tube of radium was buried, and the disease was again checked. In 1922 the growth was spreading back within the right side of the nose. The patient was subsequently lost sight of. The lesson of the case is that radical

operation should not be postponed too long. Figs. 284–287 illustrate an even more advanced case.

The place of plastic surgery in the treatment of malignant disease.—An operation for a malignant tumour has two stages: (1) the ablation of the diseased tissue with all its microscopic extensions; (2) the repair of the defect thus created.

Some surgeons have been led to adopt methods in which the first of these objects is sacrificed to the brilliant attainment of the second, with necessarily unsatisfactory results. The removal of the cancer must be the operator's sole concern in the early stage of the operation. (Figs. 284, 285.) Only when this has been done must he begin to think how the resulting gap is to be closed. (Figs. 286, 287.) If the flaps cannot be brought together, simple skin-grafting is usually the best resource. In exceptional cases, especially in the face and scalp, a plastic operation by a pedicled flap may be desirable, though rarely essential. There is a risk of concealed recurrence beneath the plastic flap. If this happens, treatment by buried radium tubes is likely to be the best resource.

Rodman, in condemning plastic procedures in breast surgery after ten years' experience, states that they secure easy primary coaptation at the expense of an abiding result, and this appears to be a fair judgment. He adds: "They are inadequate, disappointing, and do not meet the patho[illegible]sary in dealing with an in-[illegible] The primary defect with [illegible]cure to the carrying out of a preconceived plan which will do very well *in some cases* when the lesion is favourably situated, but will fail in many, perhaps most, instances where they are practised. I cannot doubt that he who employs them will find himself sooner or later the victim of shattered hopes, and definitely put them on one side as alluring and convenient for the surgeon but an enormous handicap to the patient." This condemnation appears to be none too strong.

One of the most attractive of the plastic operations for breast cancer is the method of Tansini, in which a large flap cut from the scapular region, with its pedicle near the edge of the latissimus dorsi, is brought forward to fill up the gap. To ensure the vitality of this flap the deep fascia at the edge of the latissimus must be preserved. But, if this is done, it is very probable that a portion of the permeated area of the deep fascia near the base of the flap will be left intact to reproduce the disease.

Closely related to the fallacy of allowing the treatment of the malignant growth to be influenced by the subsequent requirements of a plastic repair are ill-advised attempts to preserve structures lying in close relation to a malignant growth, simply because they are of great functional importance. As already stressed, examples of this are seen in attempts to preserve the eye when a rodent ulcer has already attacked its conjunctiva. In rectal carcinoma, attempts to preserve

be treated by a really adequate excision. Museum specimens show how inadequate and empirical are the operations performed on these growths, even up to the present time. It is common to see the skin



Fig. 289A.—Malignant melanoma in a woman of 66. Operation by the late Prof. Grey Turner. (The hand was crippled with osteo-arthritis.)



Fig 289B.—The same case. The incision healed.

(Figs. 289 and 290 from *Trans.* St. John's Hosp. Dermatol. Soc.)



Fig. 290.—The mass of tissue removed *en bloc* from the case shown in the previous figure. Sections disclosed infection of one axillary gland. Patient alive and symptom free 19 months after operation, died 21 months after operation with deposits in liver and right lung, doubtless incipient before operation.

divided within $\frac{1}{4}$-inch of the edge of the growth. Invariably, so far as I know, the area of deep fascia removed is no larger than the area of skin excised, and consequently local recurrence in the neighbourhood of the scar is very frequent.

A circular incision should be made through the skin round the tumour at what is judged by present standards to be a safe and

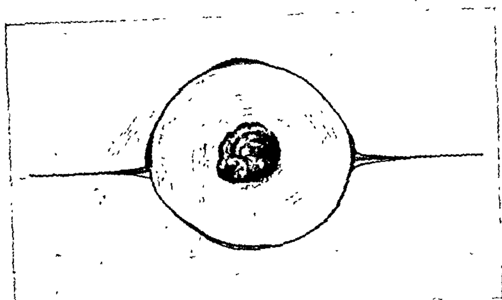


Fig. 291.—Skin incision in removal of malignant melanoma of trunk or proximal parts of limbs.

practicable distance, as a rule about one inch from the edge of the tumour. (Fig. 291.) It should be just deep enough to expose the

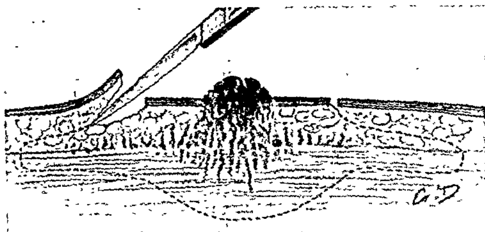


Fig. 292.—Next stage of operation seen in section: elevation of skin-flaps to obtain access for removal of adequate area of infected deep fascia.

subcutaneous fat If necessary, two radial linear incisions extending from the circular incision should be made on opposite sides of the tumour so as to facilitate the elevation of the skin-flaps, which forms the next step (Fig. 292) The skin, with a thin attached layer of

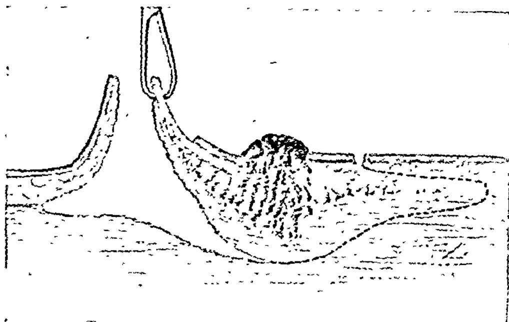


Fig. 293.—Undermining of skin-flaps has been completed.

A circle of deep fascia, 4-5 in. in diameter, has been exposed, and has been circumscribed by a ring incision down to the muscles, leaving, however, a bridge of fascia 1 in. wide, where the trunk lymphatics pass out towards the nodes. This bridge is not represented. The operator now proceeds to raise up a thin fringe of deep fascia from the underlying muscle all round for about 1 in. He next begins to scoop out, as he approaches the region of the tumour, a layer of the subjacent, presumably-infected muscle. The thickness of this layer reaches its maximum at the centre of the field of operation.

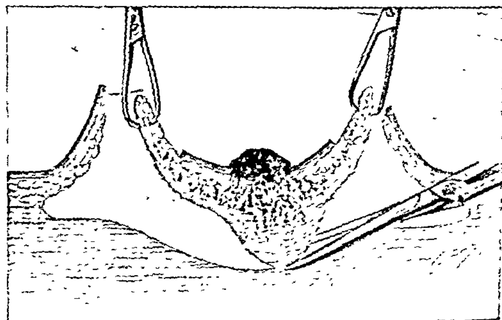


Fig. 294.—Process of cutting out infected area of muscle is nearly completed.

The excised primary growth remains attached only by the undivided bridge of deep fascia (not represented), which attaches it to the trunk lymphatics. A linear incision is now made along these lymphatics as far as the nodes of which they are tributaries. First the bridge of fascia carrying the trunk lymphatics, and next the nodes themselves, are to be excised. The specimen removed is in one piece, with the primary tumour at one end, the nodes at the other, and an intervening length of fascia. (See Figs. 289, 290.)

subcutaneous fat, is now separated from the deeper structures for about 2 in. in all directions round the skin incision. At the extreme base of the skin-flaps a ring incision down to the muscles surrounds and isolates the area of deep fascia and overlying deeper subcutaneous fat to be removed (Fig. 293). This ring incision, however, is not a complete circle. On the proximal side, where the trunk lymphatics leave the infected area of deep fascia, a bridge of deep fascia perhaps 2 in. wide is left. The isolated fascial area is now dissected up from the muscles beneath, to a line which corresponds with the circular skin incision. Finally, the mass of isolated tissues, with the growth at its centre, is freed by scooping out with a knife a circular area of the muscle immediately subjacent to the growth. It remains attached only by the undivided bridge of deep fascia which carries the trunk lymphatics of the affected area (Fig. 294).

Removal of the trunk lymphatics.—A linear skin incision is now made along the length of the limb, starting from the upper end of the existing skin incision and extending to a point directly over the first set of lymphatic nodes. The skin is reflected for 1 in. on either side, exposing a band of deep fascia 2 in. wide connecting the primary growth with the glands. Starting below, where the primary growth remains attached to it, this band of deep fascia is dissected up from the subjacent muscles until the region of the nodes is reached. Its connections above with the nodes must not be severed, but the skin incision may be conveniently sutured nearly to its upper end.

Removal of the nodes.—The incision is now extended over the region of the nodes. In the axilla a linear incision suffices, and in the groin is preferable to a T-shaped incision with the transverse limb following the line of Poupart's ligament. The latter incision is apt to be followed by sloughing of ill-nourished skin. Skin-flaps are reflected some little way, as over the primary tumour, in order to excise a certain area of the surrounding deep fascia along with the nodes. An edge of deep fascia is raised up all round, and the mass of nodes is then dissected away. It comes away still connected by a long bridge of deep fascia with the primary growth.

Removal of the next higher set of nodes.—To make the operation an ideal one, it is necessary, in the lower limb, to remove the nodes along the external iliac artery, which, though unenlarged, are probably infected microscopically. In a case operated upon some years ago, though no node could be felt above Poupart's ligament, a black enlarged node was found at operation upon the outer side of the external iliac artery. In the same case the microscope showed permeated lymphatics in the ablated area of fascia excised along with the inguinal nodes In the upper limb, if the same association is suspected, the supra-clavicular nodes should be removed. These procedures should be carried out through separate incisions, and may often be best deferred to another occasion, ten to fourteen days later, if the operation has already taxed the patient's stamina.

into an electric circuit which is completed when the active electrode of the diathermy machine touches the tissues and the current is switched on. The apparatus is controlled by a foot switch, which is usually put on and off by the operator himself. The active electrode is a fine needle or wire loop for cutting purposes, or a metal button or disc for coagulation. The heat is produced in the tissues, not conveyed to them from a heated electrode, as in the ordinary electro-cautery. The effect produced varies from a pleasant warmth to unbearable heat and coagulation of the tissues. Their contained water boils and comes off as steam, and a desiccated eschar is left.

Two dissimilar electrodes are used in surgical diathermy in which a cauterizing action is desired. A large neutral electrode, consisting of a flat metal plate usually about 6 × 8 inches, covered with lint soaked in strong salt solution (10 per cent.) is placed behind the loins or bandaged on to a limb so that it lies quite flat. The skin may be burned if this electrode is too small, if it does not make proper contact with the skin over its whole area, or if a fluid of high electric resistance such as water or *weak* salt solution is used to moisten the pad. The active electrode is a needle in an insulated handle.

Operation by diathermy.—The replacement of the scalpel by the diathermy needle as a cutting agent, though attended by technical advantages, presents some countervailing risks. Those who have not seen the method in use and have not had considerable practical experience of diathermy for smaller operations, will be well advised to adhere to the scalpel, at any rate for large operations.

Choice of apparatus.—Many forms of diathermy apparatus, quite satisfactory for medical purposes, are useless to the surgeon because they are deficient in the essential quality—rapidity of cutting with minimal cauterization effect. In order to obtain these essentials, great rapidity of alternation is necessary, and machines are made with a periodicity of from one- to two-million cycles per second or even higher frequencies. The best machines to-day are probably the Bovic—which is American and, therefore, unobtainable in this country at the moment—and those made here by the Marconi and the Genito-Urinary Manufacturing Companies.

The active cutting electrode has a sharp needle point, well insulated in a non-conducting handle. The electrode is sometimes made in the form of a knife, but the simple needle is better because it secures a maximum concentration of the current at one point, rather than its diffusion over a surface or edge. Rapid cutting is thus facilitated. Since it is the spark rather than the needle which is the cutting agent, little resistance is felt when the instrument is working properly. The tissues melt away before the needle, which should be employed delicately with light rapid strokes. Prolonged contact of the needle at any one point should be avoided, as it is certain to produce local necrosis and to imperil primary union.

The diathermy needle may be employed for two distinct purposes—either to coagulate at a point and produce hæmostasis or, as a substitute for the scalpel, for all ordinary cutting purposes. The type of current used for these purposes varies.

When the first edition of this book was published, diathermy, used in one or other of these two modes, had largely replaced the knife in the treatment of cancers of the oral cavity. If an oral growth has to be excised, diathermy remains the best method. But, in this field, diathermy is now seldom employed because radiotherapy gives better results, with less destruction and disablement.

On the other hand, the scope of diathermy has been extended in dealing with those malignant growths in which radiation treatment has not replaced operative removal as the method of choice.

Advantages of diathermy. Loss of blood minimized.—As contrasted with the scalpel, the diathermy needle possesses various advantages. It seals off all the smaller vessels in the plane of section, which may remain almost completely dry: thus, the loss of blood is reduced to a minimum. Any artery which bleeds is seized with forceps, and may be subsequently tied or, if a small one, it suffices to touch the forceps hanging from it (held up out of contact with the rest of the tissues) with the terminal for a moment. Slight charring and bubbling occur at the point of the forceps, which may then be removed. Small bleeding points that can only just be caught can be controlled in this way. This method is unsafe for vessels of any considerable size; most named arteries should be ligatured (Wilson Hey*). It saves time for the smaller vessel, and bleeding in hidden places is more easily controlled. Wilson Hey has found it most valuable in prostatectomy. It should not be used for vessels on a thin flap, as the overheating of such a flap may lead to sloughing.

In the control of hæmorrhage by this means there is supposed to be a great saving of time and labour.

Avoidance of shock.—Perhaps the greatest advantage of diathermy is that it appears to divide nerves without stimulating them, and thus without causing shock. It is certain that diathermy does not stimulate the motor nerves, though faradic undertones of the current may occasionally cause muscular contraction. A similar indifference to the diathermic current may be postulated for the sensory nerves. The pain of surgical diathermy is apparently not due to division of the nerves but to the heating of the adjoining tissue.

Elimination of chill, local and general.—Most extensive operations necessitate prolonged exposure of tissue surfaces and consequent loss of body-heat. By eliminating chill the diathermic method removes one source of shock. The whole cone of tissue intervening between the large neutral electrode and the cutting point has its temperature raised, the heating effect is thus a systemic as well as a local one.

* *Brit J. Surg* (1945), xxxii, 129 (July).

In operations on the breast, which involve the cutting of long, badly-nourished flaps, especially liable to chill, and the exposure of a large area of chest-wall denuded of muscle, this effect of diathermy is valuable, but the risk of over-heating the flaps must not be forgotten.

Avoidance of implantation.—In cancer surgery diathermy minimizes the risk of the implantation of cancer-cells on the wound. If the scalpel happens to cut across a group of cancer-cells, viable cells are set free in the wound. The diathermy needle destroys a microscopic layer of cells on either side of its plane of section, sterilizing the wound as it goes. Any lymphatic vessels cut by the diathermy needle will be sealed off.

Perhaps the chief use of surgical diathermy to-day is in the surgery of the central nervous system, a coagulating current being used to thrombose and seal the delicately walled vessels of the brain which may be controlled only with difficulty by other methods. This is particularly applicable to the surgery of intracranial tumours. Prior to the introduction of this method by Harvey Cushing, the removal of the meningiomata, most of which are comparatively accessible, was fraught with great hazard and a high mortality from hæmorrhage. Diathermy has changed the whole picture and very materially lowered the mortality of such operations.

Dangers and disadvantages of diathermy. Risk of explosion.—No open anæsthetic, the vapour of which forms an explosive mixture with air, may be used during diathermy. Serious and even fatal accidents have occurred from the use of ether. Chloroform or gas and oxygen are generally employed, or other non-explosive vapours in a closed apparatus. If any spirituous solution has been applied to the skin just before the operation it must be carefully mopped dry before the diathermy is switched on, or it may catch fire

Damage to important structures.—Only a practised operator with a nicely regulated machine may venture to use the diathermic needle in the neighbourhood of large vessels and nerves or other vitally important structures. It is easy to penetrate a large vein or so to devitalize its wall that secondary hæmorrhage will occur. For dissection of the axilla the method is unsuitable.

Occasional impairment of primary union.—Primary union takes place satisfactorily after even very large cutting operations by diathermy if the cutting has been done rapidly, without visible charring of the cut surface, and without undue heating of the subjacent tissues. If these conditions are not fulfilled, and of course if there is failure in asepsis, suppuration is probable. A likely cause of failure is the omission to sterilize the handle for the needle and the cable which connects it with the machine. Sterilizable cables are obtainable and should be insisted upon.

About ten days after a diathermy operation there may be a phase

of lowered resistance to the patient's own skin organisms, indicated by a rise of the previously normal temperature, and by reddening of the skin edges of the wound. The irritation usually subsides rapidly when suitably treated, but in rare cases suppuration may appear and may extend under the flaps. The process seems to be a kind of fat-necrosis.

Phlebitis.—The application of the neutral electrode to the thigh should be avoided. In two patients, who had previously suffered from phlebitis, acute saphenous and femoral phlebitis occurred after the operation, and one of them succumbed to a staphylococcal septicæmia.

Burns from the plate electrode.—Any uncovered part of the neutral or plate electrode will burn any portion of skin touched by it, since the current, following the line of least resistance, will concentrate upon the uncovered area. The plate electrode should be wrapped completely in several layers of a towel wrung out of strong saline (a handful of salt to the pint). It is best placed behind the loins, with a small cushion-like pad beneath it to hold it in close contact with the skin, aided by the weight of the patient.

Most of the dangers associated with diathermy are avoidable with due care.

I habitually used diathermy in the radical operation for breast cancer for ten years, but have lately come to the conclusion that the scalpel is preferable for such a large operation. As a matter of fact, the method, though extensively tried out, has never been generally adopted in this country except in operations on the central nervous system.

Coagulation diathermy.—If the surgeon decides not to cut out a tumour in a difficult or inaccessible situation, it may be destroyed *in situ* by diathermy. The needle electrode is plunged into the tumour and carried down to within 1 cm. of its deep aspect. The current is turned on until an area of coagulation 1 to 2 cm. in diameter appears round the needle, which is then removed and re-introduced about 2 cm. away from the first puncture. The process is repeated until the whole area has been dealt with. Alternatively, a heavy coagulating current may be passed through a loop electrode which is used to remove slices of the tumour

As a cauterizing agent the diathermic needle is much more efficient than the Paquelin or electro-cautery, because its range is greater. If the current is kept on for too long a dry eschar of high electrical resistance forms round the needle, sparking occurs, and the needle adheres to the destroyed tissue so that bleeding follows its withdrawal.

Risks of coagulation diathermy.—When diathermy is used to coagulate and destroy an area of tissue *in situ* with a view to its subsequent separation as a slough, the process of separation is an inflammatory one attended by certain risks. Œdema always occurs round the coagulated area and lasts for several days. Œdema of the glottis

may supervene if the growth is near the superior aperture of the larynx. Stricture may follow diathermy of an œsophageal growth, causing obstruction possibly necessitating gastrostomy. In the mouth, secondary hæmorrhage may occur, for the sloughs often become very foul. Broncho-pneumonia is also a complication to be feared. As a rule, *separation of the sloughs is accompanied by little pain*, and the wound heals well.

Great caution must be used in employing diathermy close to a bone, for necrosis is likely. In some cases the risk must be accepted, if the alternative is incomplete destruction of malignant tissue.

Other uses of surgical diathermy are in the fulguration of papillomatous bladder tumours, the endoscopic removal or intra-vesical treatment of certain forms of prostatic enlargement, or for dealing with bleeding points.

Operative Treatment of Recurrence

It is difficult to lay down clear rules for the operative treatment of recurrence. If, however, the recurrence is single, movable and accessible, prompt operation should be performed, unless upon consideration it is decided that radio-therapy is preferable. In this choice the feelings of the patient will play a great part. The issue of a recurrent case is necessarily uncertain, and it is as unfair to thrust operation upon a reluctant patient as to refuse it to one eager to seize every chance. Frequently the ideal treatment is a combination of excision and radiation.

Of course, a recurrence, even if single, is likely to be followed by recurrence at other points, but this is not inevitable, especially if thorough X-ray treatment is given subsequently. Sometimes after excision of the recurrent lump the patient remains well for years or even permanently. In order to exclude other recurrences, operation *should be preceded by a specially thorough examination of the patient*, and by radiological examination of the chest. *A pelvic examination* should always be made.

CHAPTER XIII

OPERATIONS ON THE BREAST

By W. SAMPSON HANDLEY

MAMMARY CANCER

Lymphatic anatomy. Axillary glands.—Poirier and Cunéo describe the lymph-glands of the axilla as grouped in three main chains, following respectively the axillary, the external mammary, and the subscapular arteries, and converging to an apical group of subclavicular glands. In addition, there is a central group embedded in the fat of the axilla.

1. The *humeral chain*, comprising four or five glands, accompanies the axillary vessels, lying internal to the vein. Glands forming a downward continuation of this chain follow the upper course of the brachial artery, and may be found cancerous in some late cases of breast cancer—a fact first pointed out by Lockwood. The humeral glands receive most of the lymphatics of the arm. Their efferent vessels terminate in the central group, the subclavicular glands, and in a gland situated above the clavicle in the subclavian triangle.

2. The *thoracic chain* consists of two or three glands placed in the second or third intercostal space in front of the trunk of the external mammary artery, just under cover of the lower border of the pectoralis major. These are the glands first affected in cancer of the outer part of the breast. In addition, there are in this group two or three glands placed behind the external mammary vessels in the fourth and fifth intercostal spaces. The most constant of these glands is situated in the fourth space in the mid-axillary line. It is sometimes described as the para-mammary gland. The anterior thoracic glands receive lymph mainly from the breast and the muscles lying behind it; the posterior thoracic glands receive lymphatics from the lateral wall of the thorax. The efferents of the thoracic chain mostly end in the glands of the central group, but generally a few vessels pass direct to the subclavicular glands.

3 The *scapular chain* of six or seven glands lies along the subscapular artery in the groove separating the teres major from the subscapularis, and is sometimes affected early in breast cancer, though its afferents mainly come from the scapular region. It empties into the humeral and central glands.

4 The *central group*, three to five in number, lies near the base of the axilla, and receives efferents from the preceding groups, having no lymphatic territory of its own. Efferent vessels pass to the subclavicular glands.

5. The *subclavicular* glands (often called subclavian glands) consist of six to twelve glands lying at the very apex of the axilla, below the clavicle, above the pectoralis minor, behind the great pectoral and the

costo-coracoid membrane, and internal to the axillary vein. It is best not to call these glands subclavian, for the name, though literally accurate, suggests a relation to the subclavian artery which they do not possess. Internally, they rest on the first digitation of the serratus magnus. They possess great surgical importance, for they are often affected early in breast cancer, and their position enables them to elude the inexperienced operator. One of the glands of the group often lies in front of the axillary vein, in a prolongation of the axillary fat which passes upwards across the vein towards the tip of the coracoid process, under cover of the pectoralis minor.

The afferent vessels mostly come from the other axillary glands which converge to the subclavicular glands. They also receive a vessel running along the cephalic vein, and a branch accompanying the acromio-thoracic artery, which comes from the breast through the great pectoral (Rotter). This vessel may bring about the infection of the apical glands in breast cancer before the lower axillary glands are invaded—an important surgical fact. The efferents of the subclavicular glands, after forming a plexus, unite into a single trunk, which runs in front of the subclavian vein, behind the subclavius muscle, to terminate in the great veins in the angle where the internal jugular joins the subclavian vein. *It is important to notice that nearly always one of the efferents of the subclavicular group passes into a gland in the subclavian triangle, and this may be one route by which the supraclavicular glands are attacked.*

Internal mammary glands: (*syn.*, retrosternal, parasternal, sternal, anterior mediastinal glands) —The internal mammary glands lie along the artery of the same name, half an inch outside the margin of the sternum. In front of them are the anterior intercostal fascia and the internal intercostal muscles; behind them lie the internal mammary artery and vein, and the pleura, which in this situation is very thin. The gland in the third space has behind it the triangularis sterni.

Mr. Philip Stibbé re-investigated the anatomy of these glands. He found four or five on each side, one each in the first, second, third and fifth or sixth spaces.

In breast cancer they possess capital surgical importance, for when they are infected the disease has become intrathoracic. They receive, along the course of the perforating branches of the internal mammary artery, small tributaries from the pectoral lymphatic plexus, which, of course, is connected directly with the breast.

The efferent vessels of this chain of glands unite into a single trunk which empties itself into the anterior surface of the junction of the internal jugular and subclavian veins. It is, however, important to notice that frequently one of the efferents is tributary to a gland in the subclavian triangle lying just superficial to the subclavian artery, and that gland infection of the neck frequently if not invariably arises by this route.

It should be noted that the parasternal glands are interconnected by a plexiform chain of lymphatic vessels extending from the level

of the subclavian vein down to the diaphragm, and that they receive as afferents lymphatic vessels comitant to the intercostal arteries of the upper intercostal spaces. The chains of the right and left sides communicate behind the sternum, so that if one chain is invaded spread to the other is likely to follow soon. It should be noted particularly that the internal mammary lymphatic chain for much of its extent is separated from the parietal pleura only by a thin layer of cellular tissue. Even nearer is the rich parietal subpleural lymphatic plexus Permeation of this plexus may lead to the escape of cancer cells into the pleural cavity followed by pleural secondaries with effusion, and death within a few months.

Clinical course of parasternal invasion of the thorax.—When by an adequate operation other routes of dissemination are eliminated, dissemination from an infected parasternal gland usually runs a characteristic course and may be a very slow process, taking in some cases ten years or more to a fatal issue. Often the first clinical sign of it is the appearance of a nodule at the sternal end of an intercostal space, usually the second or third, followed in a descending order by the appearance of similar nodules in the two or three spaces next below. The sternum itself is often attacked. Next occurs a spread of small fascial nodules outwards from the sternum along the infected spaces, and perhaps nodules may be found at the margin of the sternum on the opposite side. Enlarged glands now appear in the supraclavicular triangle on the side of the growth, and in the opposite axilla, later nodules appear in the opposite breast. Next comes impairment of resonance over the first piece of the sternum, due to a mass in the superior mediastinum which may cause dysphagia or dyspnœa. Within a few months of the end pleural dullness at the base on the side of the growth supervenes. There may be pain down the sternum, but usually it is absent, and a short illness like a broncho-pneumonia is the terminal event. Exceptionally the abdomen may be attacked by extension of permeation downwards to the diaphragm and falciform ligament, and thence to the liver. It is probable that in some cases parasternal invasion gives rise to no clinical signs until a very late stage

In 1927* I stated: "In order to find the reason for the increased gravity of prognosis associated with enlargement of the axillary glands we must turn to the parasternal glands of the internal mammary chain. If the axillary glands are infected then probably so too are the parasternal glands. The clearance of the axilla is easy and locally effective, but our results have been marred by failure to recognize and deal with the more subtle and clinically unrecognizable process of parasternal invasion."

I have long suspected that infection of the internal mammary glands is frequent and early. In a group of 26 cases of recurrence, analysed in 1922, I found five in which the return of the disease occurred along the

* "Parasternal Invasion of the Thorax in Breast Cancer," W. S Handley, *Surg Gyn & Obst* December, 1927, p 721

margin of the sternum in spaces 1, 2 or 3, and nine in which it returned in the supraclavicular glands. Thus 14 recurrences were probably due to infection of the internal mammary glands before operation. I removed glands from the upper three spaces in a short series of cases, and in two of them found infected glands, but I decided in future to trust to radium insertion at the time of operation. Since recurrence usually shows itself in the supraclavicular region or the second space, less often in the first or third space, I began as a routine to insert radium tubes internal to the axillary vein at the apex of the axilla and in the intercostal spaces 1, 2 and 3, at their inner ends. Recurrence in these spaces has since been very rare in my records, but in four cases a return of the disease as a solitary nodule at the inner end of the *fourth* space has been noted. I have been slow to learn the lesson that the *whole length* of the chain must be radiated and not merely its upper half. Infection of the internal mammary glands may occur even before the axillary glands are attacked, as I showed in a case recorded in detail in 1927, and by the time of operation may have spread up and down along the whole length of the chain without giving rise to any clinical sign of its presence.

It is evident that unless means can be found to deal with this menace, recurrence after operation will continue to be frequent. The method of dealing with it is discussed on p. 725. It still seems doubtful whether X-ray treatment can effectively reach the internal mammary chain, sheltered as it is by the costal cartilages.

The extreme importance of the internal mammary lymphatic chain in breast cancer has lately been fully established by the important work of R. S. Handley and A. C. Thackray.* These authors have shown that carcinomata in the inner half of the breast may metastasize to the internal mammary chain at the same time as, and sometimes before, the axillary glands are invaded. Where the carcinoma is in the outer half of the breast invasion of the axillary glands usually occurs first, but is followed with no great delay by invasion of the internal mammary chain. Microscopic evidence from 50 cases showed that 38 per cent. of their 50 patients had deposits in the internal mammary glands at the time of operation, and this in a series which was consecutive except for the exclusion of the very advanced cases. The usually accepted four-stage clinical classification of breast cancer is torpedoed by this work, which shows that many cases classified as belonging to Stage 1 (axillary glands uninvaded) and Stage 2 (axillary glands infected but still mobile) are really in Stage 3 at the time the patients first seek advice.

R. S. Handley and A. C. Thackray† continued their investigations on internal mammary gland involvement and in 1951 reported on 100 cases. Broadly speaking, in one-third of the cases neither axillary nor internal mammary glands were invaded, in one-third only the axillary glands; in the remaining third the internal mammary glands

* *Lancet*, 1949, ii, 276, also *Brit Med Journ*, Jan 9th, 1954

† Report for 1951 of the British Empire Cancer Campaign, p. 62.

showed cancerous invasion accompanied, except in four cases, by invasion of the axillary glands. In three of these four cases the primary growth was in the inner half of the breast.

The authors report on the subsequent history of their first fifty cases. Of the gland-free cases 6 per cent. have died, of those with axillary invasion but with intact internal mammary glands 38 per cent. are dead. Seventy per cent. of those with both sets of glands invaded are already dead. Since all cases with gland invasion received post-operative X-ray treatment, this fact confirms my doubts whether X-radiation can sterilize the well-protected internal mammary chain. The last case of this early series was operated on about three years prior to the report.

Urban (1951) and others have attempted, by severe operations involving the bony thorax, to excise the internal mammary lymphatic chain, but I believe the real answer to its menace is precision radiation by buried radium tubes inserted at the end of the current radical operation (*see* p. 725); a policy I have adopted since 1921, though for years I made the mistake of irradiating only the upper part of the chain.

The supraclavicular glands consist of three main groups:—

1. A chain accompanying the spinal accessory nerve and passing beneath the trapezius.
2. The lower part of the internal jugular chain lying on the outer side of the internal jugular vein under cover of its sheath. *The main efferent of the internal mammary chain may discharge into the lower gland of this group.*
3. A transverse cervical chain lying just above and parallel with the clavicle in company with the transverse cervical artery.

Recent work has emphasized the importance of the supraclavicular glands. M. Andreassen and E. Dahl-Iversen* of Copenhagen removed the supraclavicular glands in 90 cases of radical operation for c. mammæ —cases without any clinical evidence of supraclavicular infection. They found microscopically infected glands in 17 per cent. of all cases and in 33 per cent. of cases with axillary gland involvement. They advise removal of the supraclavicular glands followed by post-operative radiation in all cases of the latter class. They find no advantage in pre-operative radiation. In an earlier study of 103 cases of radical operation the same authors found, among 63 cases of recurrence, 13 (21 per cent.) where the disease first returned in the supraclavicular glands.

Evolution of the treatment of breast cancer.—A very brief history of opinion and practice in the treatment of breast cancer may have some practical value. In 1867 Charles Moore at the Middlesex Hospital, stressing the local origin of cancer, insisted upon the removal of the whole breast and of unsound adjoining structures, including the axillary glands. In 1882 Mitchell Banks gave similar advice, and insisted on

* *Journal Internationale de Chirurgie*, Jan., 1949, p 27.

the routine removal of the axillary glands, as did also Samuel Gross in 1888. Sir Harold Stiles in 1892 demanded the fashioning of extensive skin-flaps so that the outlying portions of the breast could be reached and the organ completely removed.. He found that cancerous lymphatics are frequently present throughout the breast, and his teaching was followed by Sir Watson Cheyne (1893).

W. S. Halsted (1894) was the first to advocate routine removal of the sternal portion of the great pectoral muscle. In some other respects his operation was inferior to that of Stiles and Cheyne, removing an unnecessary amount of skin, but not fashioning skin-flaps, so that the removal of the subjacent deep fascia was inadequate. It was Halsted who converted world opinion to the necessity of a wide monobloc operation, and any operation of a radical nature is often loosely called by his name.

In 1906 I showed the danger of invasion of the abdomen through the epigastric deep fascia and advised the removal of the upper part of the anterior layer of the rectus sheath. Abdominal recurrence, formerly common, is now rare in consequence. I also showed that the disease, when it reaches the limits of the breast, continues to spread by permeation in the lymphatic plexus of the deep fascia, and advocated the removal of a circle of deep fascia, 10–12 in. in diameter and centred *upon the primary growth, as perhaps the most important step of the* operation. My operation proved satisfactory in preventing local recurrence, which is now very unusual.

Late recurrences at the edge of the sternum and in the supraclavicular glands remained frequent. I traced them to invasion of the internal mammary chain of glands before operation.* Since 1920 I have introduced radium tubes at the time of operation to deal with this danger (*see* p. 725), and "parasternal" recurrences *in the spaces radiated* have since almost disappeared from my practice. Radiologists who are not anatomists have failed to realize that radium tubes can with certainty be brought into close proximity to the internal mammary glands, and have criticized the method as a "hit or miss" one, or as failing to secure "a uniform field of radiation", but it has been justified by a 10-per-cent. reduction of three-year recurrences

I note with some concern that local irradiation of the internal mammary glands at the time of operation has not been generally adopted It is a rational step, based on a combination of clinical and pathological evidence. I am not convinced that external radiation can effectively replace it. Adair and Stewart, at the Memorial Hospital in New York, subjected 39 cases of operable breast cancer to radiation by a 4-g. radium pack at a distance of 6 cm., using five ports and giving 20,000 to 44,000 m.c.hr. per port. In spite of this vigorous treatment, on subsequent operation viable cancer cells were found in the breast in 28 per cent and in the glands in 73 per cent. of cases.†

Buried-tube radiation.—In 1924 Mr. Geoffrey Keynes began to

* *Surg. Gyn Obst*, Dec., 1927, xlv, 721
† *Ann. of Surg*, 1935, cii, 254

employ buried radium as a complete substitute for operation, choosing at first fifty advanced or inoperable cases. Six of these patients were alive ten years after treatment, of whom five were free from recurrence. Many of them lived for periods up to eight years without external signs of disease. For this class of case Keynes' method constituted a great advance.

In 1928 I pointed out the difficulty of ensuring adequate radiation of such a large volume of tissue as is represented by an adipose breast together with the whole contents of the axilla. I concluded that "operation still remains a necessity to remove the bulk of the disease and to reduce the proble [illegible] le proportions. For the present, at any [illegible] be colleagues, not competitors. To u [illegible] it a dangerous antagonist with only one hand." I think this is still true.

Restricted operation combined with buried-tube radiation.—The disadvantages of buried radium alone were thus described by Mr. Keynes in 1937.*

> "The patients were carefully observed and in due course a certain number of failures were noted. These failures were either shown by incomplete disappearance of the primary tumour or by the appearance of recurrent nodules in the breast or in the skin. In a number of patients these residual tumours were removed and examined nine months or more after the irradiation. It was then found that in 50 per cent. no discoverable cancer remained, the tumour consisting entirely of fibrous tissue. In the other 50 per cent. there was evidence of active cancer. This result led to a reconsideration of the procedure, and it was realized that the failures might reasonably be attached to the physical limitations of radium needles. The penetrating power of the rays is strictly limited and many of the tumours were too thick and bulky for the gamma-rays to penetrate them effectively, so that the cancer cells at the centre or at the surface did not receive a lethal dose. The bulk of the tissues to be irradiated did seem to be a serious obstacle unless the dosage of radium were to be greatly increased, and to this there were other objections."

Moved by these considerations, Mr. Keynes now began to remove either the tumour or the breast before irradiation according to circumstances, but without removing the pectoral muscles or clearing the axilla. He claimed that axillary recurrence never takes place, a claim which my own experience leads me to doubt, and summarized his policy as follows:—

1. Local removal of tumour if it is large or the diagnosis is uncertain, followed by radium.
2. Local removal of the breast if the tumour is very bulky, followed by radium.

* *Brit Med. Journ*, Oct. 2, 1937, ii, 643

3. Never dissect the axilla.
4. Radium by itself may be used: (*a*) if the tumour is of moderate size and the diagnosis certain on clinical grounds; (*b*) if the patient refuses operation.

From the statistics he gives, based on 250 cases, the results of Keynes' treatment in operable cases appear within the limits of error to be neither better nor worse than the results of operation alone.

Keynes frankly states the disadvantages of his method: 1. The results are difficult to interpret, since residual lumps which may or may not contain living cancer cells are frequently found. 2. Post-irradiation fibrosis may appear as late as two years after treatment in the positions where irradiation has been most intense. Fibrous lumps may appear on the inner wall of the axilla, and may arouse suspicion of recurrence. 3. There is an increased liability to neuralgia or "rheumatic pains" in the treated area. 4. Post-irradiation fibrosis of the pectorals may produce limitation of movement.

It thus appears that in 1937 the originator of the "buried rapium alone" policy for breast cancer had receded from the position he originally adopted with regard to radium in breast cancer. He still avoids extensive dissection of the axilla, but removes obviously enlarged glands. Restrictions on the use of radium during the war, and the increased effectiveness of X-radiation have led him to adopt a full course of deep X-rays instead of radium for the post-operative treatment.

According to Todd and Dawson* the Keynes method has been almost completely given up in Edinburgh. Of 32 cases treated from 1930 to 1932 only five survived five years, of which four were stage 1 without palpable axillary glands. I believe that a combination of radical operation with simultaneous radium-tube radiation is best for the average case of breast cancer. Difference of opinion still remains as to the relative scope of these two elements. While some surgeons would trust to radium for the outlying extensions of the tumour in and beyond the breast and in the axilla, others, myself among them, regard the present tendency to experimental restriction of the operation as dangerous. Admitting that an operation is necessary, the present radical operation is so safe and so free from discomforts and sequelæ, that there seems little reason to modify it. Mr. Keynes stresses the mutilation it produces and the immediate risk to life, which he places at 3 per cent. He speaks of brawny arm, as a not infrequent sequela, and thinks that the operation sometimes produces widespread local dissemination.

His impressions are not in accordance with the facts as I have found them in my own experience. The mortality of the operation is small, pain and shock are absent or slight, and a brawny arm resulting from the operation is hardly ever seen. Axillary recurrence is very rare. It may be questioned whether on the average a partial removal

* E. and S. Livingstone, Edinburgh, "*Cancer*," 1937, p. 39

of the breast gives a better cosmetic result than complete mastectomy. Restriction of movement from fibrosis of the pectoral muscles is not rare after radiation, so that functionally the radical operation probably gives a better result. A puckered breast can hardly be beautiful, and radiation always causes fibrosis. Psychologically the long period of waiting for the lump to disappear, and doubts as to the nature of any residual lump, impose a strain on the patient and her medical advisers which may prove in the long run much greater than that of a radical operation.

It is at present too soon to estimate the value of the method of local excision plus implanted radium, and personally I do not feel able to recommend it with confidence as a routine though it would seem especially suitable for the aged.

On the whole I conclude that the standard treatment for breast cancer should be radical operation, with implanted radium in the supraclavicular triangle and along the internal mammary glands. This rule applies especially to—

1. Patients with voluminous breasts in whom, unless the growth is unusually early, the mere volume of tissue to be radiated may be an insuperable difficulty.
2. Left-sided breast cancer in patients with cardiac weakness or disease likely to be aggravated by heavy radiation.
3. Patients with operable but ulcerated and septic growths. Extensive sloughing may follow the use of a large dose of radium in such cases.

In a large percentage of cases, excluding those just mentioned, the patient may be offered a choice between (*a*) radical operation with parasternal buried radium followed by a short course of deep X-rays, (*b*) limited excision with buried radium, (*c*) buried radium alone, and (*d*) simple mastectomy and subsequent X-ray treatment by the Edinburgh method of Dr McWhirter. My view is that the first alternative offers a greater measure of security and a more immediate relief from anxiety, at the cost of a small operative risk.

In certain cases, I would definitely advise implanted radium in preference to operation. If the growth is infiltrating the intercostals or if the axillary glands are fixed, implanted radium may, nevertheless, give valuable and prolonged palliation. It may be combined with limited diathermic removal of an ulcerated growth.

Also, in small growths starting at the periphery of the breast, and often also in carcinoma of the male breast, radium implantation with local excision of the growth seems to hold the advantage over radical operation, owing to the difficulty of centring the operation on the primary growth, and, in the male, to the difficulty of fashioning skin-flaps. It is also preferable in old patients. A patient of mine aged 87 when treated by buried radium, died without recurrence at the age of 95.

Restricted non-radical operations for breast cancer.—For several

reasons no final dogmatic statements can be made as to the "best" treatment of breast cancer. Radiation treatment remains in the evolutionary stage, with restricted powers increasing by degrees, but still undetermined. Further study is needed as to the paths of spread of the disease, e.g. from the parasternal glands along the upper intercostal spaces to the spine. Statistics of operative results are discordant, and hitherto give no clear guidance because they have been based on a defective clinical classification of the "stages" of breast cancer.

Some account must be given of recent attempts to limit the scope of the radical operation and to lean more heavily on radiation treatment.

Pre-operative radiation followed by simple mastectomy has its advocates, and may be employed if for any reason the operation has to be postponed. However, the retention of the breast impedes the access of radiation to the deeper parts. Irradiated tissues may be slow to heal, and the patient's pre-operative ordeal of anticipation is unnecessarily prolonged.

Treatment by local mastectomy alone or with implanted radium with or without removal of the axillary glands.—Instead of excising merely the primary lump by the Keynes method, some surgeons have trusted to a simple mastectomy alone; others to simple mastectomy accompanied by radium implantation or followed by X-ray treatment. The first alternative seems quite empirical and irrational and is a clearly retrograde step. The second alternative has yet to prove its desirability. W. L. Harnett* studying the survivorship of 93 cases of simple mastectomy alone found 38 survivors (40·9 per cent.). Of 57 cases of simple mastectomy with radiotherapy, 24 (42·1 per cent.) were found still living. In a further 83 cases of simple mastectomy with removal of the axillary glands about 36 per cent. were found surviving, whether or not radiotherapy had been employed. Harnett divided the 83 cases in which the axillary glands were removed into Stage I and Stage II cases.

		Local mastectomy alone	*Local mastectomy. Axillary glands removed*
Survival Rates	Stage I	55·1%	66·6%
	Stage II (axillary glands infected)	14·3%	35·7%

The length of survivorship is not stated Harnett says the figures "are not statistically significant", but surely they strongly condemn failure to remove the axillary glands.

Local mastectomy followed by X-radiation—At the Royal Infirmary, Edinburgh, in the period 1941–45, Dr. R. McWhirter† reports that 941 cases of operable breast cancer have been treated by simple

* *British Journal of Cancer* 1948 ii 212 and *Lancet* 1949, i, 886
† *Proc. Roy. Soc. Med.* vol xli Sect Surg No 1, Feb 1948

mastectomy and post-operative X-ray therapy with a five-year survival rate of 55·9 per cent. The survival rate is calculated by a method which takes into account cases operated on less than five years previously, and thus appears to contain an element of prophecy. In 1930–34 radical surgery alone in operable cases gave a five-year survival rate of 35·6 per cent., in 1935–40 radical surgery and post-operative radiotherapy gave a survival rate of 44 per cent.

It is evident that this Edinburgh method limits the share of surgery in treatment to the removal of an obstacle—the breast—which impedes access of radiation to the deep extensions of the tumour. The results appear to indicate a considerable advance in radiation technique. The X-ray treatment is begun within a fortnight of the operation, with a minimum voltage of 250 k.v. The chest wall is treated by tangential or glancing fields to avoid lung-fibrosis, and the tumour dose delivered over an unspecified area is 3,750 r. over a period of three weeks Special attention is given to the axilla.

Further reports on the Edinburgh treatment will be awaited with interest. Dr. McWhirter considers it inapplicable in stout patients because of the difficulty of getting an adequate depth dose in the axilla. He says:—" Before the method is more widely adopted it is important to appreciate that simple mastectomy and a low standard of radio-therapy will be associated with results poorer than those obtained by the radical operation without any radio-therapy."

It may be added that proof of the ability of X-rays to deal with parasternal gland invasion awaits a review of Dr. McWhirter's cases in five or ten years' time; meantime judgment on the method must be suspended.

Can X-radiation replace operation?—Owing to the complex lymphatic connections of the breast a large surface area extending from the neck to the epigastrium and from the sternum to the edge of the latissimus dorsi must receive treatment. To be effective a lethal dose of rays must penetrate at least to the deep fascia, to the apex of the axilla, and through the costal cartilages and intercostal spaces to the internal mammary glands. In stout subjects some inches of fatty tissue protect the deeper parts of the growth. Dosage is limited not only by consideration for the skin, but by the risk of lung fibrosis and of constitutional depression. Lung fibrosis developed in seven out of 16 patients treated by X-rays alone at the New York Memorial Hospital.* In past years I have seen secondary nodules actively developing in areas subjected to the intense Erlangen treatment, now abandoned on account of its severity.

It seems fair to conclude that, except in rare early cases, the problem of treating breast cancer by X-rays alone is so difficult as to be at present insoluble. In inoperable cases they may be a useful palliative.

Can surface radium treatment replace operation? To this question also the answer must be in the negative. A dose which the skin can

* J L Leach *et al*, *American Jnl. of Roentgenology*, May, 1942.

tolerate is unlikely to be effective when it reaches the deeper parts of the breast.

Mode of spread.—It is evidently of great importance to surgeons to know in detail how breast cancer spreads. The statistics of diverse methods of operation are an uncertain guide to the ideal method. Here, as in other medical matters, statistics can only occupy a secondary place as supplying confirmatory evidence of conclusions already reached by pathological research.

Some years ago I tried to rationalize operative methods in breast cancer by a careful study of the phenomena of dissemination. The pioneer work of Stiles and Heidenhain had been restricted to the spread of cancer within the limits of the breast itself, and did not produce, even in the minds of those authors themselves, any doubt as to the theory of dissemination then current, namely, the embolic or water-carriage theory. The cancer-cells set loose from the primary growth were imagined to be swept along like driftwood by the lymph- or the blood-stream until arrested in some narrow channel. There can, of course, be no doubt that such lymph-emboli are the agents which infect the axillary glands in an early stage of the disease. But a study of the other secondary deposits accessible to observation, viz. those in the skin and bones, shows that these deposits, beginning near the primary growth, spread in a centrifugal manner from it. This is illustrated, for bone deposits, in the following table :—

FREQUENCY OF CANCEROUS DEPOSIT OR SPONTANEOUS FRACTURE IN 329 CASES OF MAMMARY CANCER AT THE MIDDLESEX HOSPITAL*

	BONE	NO. OF CASES	PERCENTAGE OF TOTAL
Bones lying wholly or partially within the area liable to subcutaneous nodules	Sternum	30	9·0
	Ribs	28	8 0
	Clavicle	5	1·5
	Spine	12	3·6
	Cranial bones	9	2·7
	Scapula†	1	0 3
	Femur	14	4·2
	Os innominatum†	0	0 0
	Humerus	9	2·7
Bones lying beyond the area liable to subcutaneous nodules	Radius	0	0·0
	Ulna	0	0 0
	Tibia	1‡	0·3
	Fibula	0	0 0
	Patella	1‡	0·3
	Bones of hand	1	0·3
	Bones of foot	0	0·0

Subcutaneous nodules are found to obey the sam[illegible] They appear first near the primary growth and spread from it[illegible] [illegible]er and larger circle, but this circle ha[illegible] spreads below [illegible] or below the

* Sampson Handley, *Cancer of the* [illegible] 32.
† This bone owing to its shape, [illegible] spontaneous fract[illegible] under observation at an autopsy.
‡ Knee ankylosed, femur [illegible] with extension [illegible] head of tibia.

knee, because the patient dies before it has been able to reach the fore-arm and the leg. Yet it is in the distal ends of the limbs, above all other places, that the effects of embolism might be anticipated.

These exceptional cases of very extensive centrifugal spread show on

a lesser extent in every case of breast

of the skin and subcutaneous tissues

from the primary growth, there will

be found in them, at points near

Farther out, at a varying distanc

a narrow and elusive zone a few



Fig. 295.—Permeation of the pectoral fascia in breast cancer before the breast has become adherent to the fascia. The axillary glands were free from growth. ×85.

A Loose areolar tissue between the breast and the pectoral fascia. B: Pectoral fascia showing darkly-stained permeated lymphatic vessels. C, Pectoral muscle.

deep fascia where its lymphatic vessels are choked by cancer-cells. Beyond this zone only normal tissues will be seen. The zone occurs in each of the radiating strips, and is a section of a large circle which constitutes the true growing edge of the disease. This *microscopic growing edge* may be found at any distance up to 2 ft. from the primary growth, and its detection is the foundation-stone of the permeation theory of dissemination. By permeation is understood the choking up of the lymph-vessels by the growth in continuity of cancer-cells along them.

The facts can only be explained as follows: The immense prolifera-tive pressure of the epithelium at the primary focus forces cancer-cells into the lymphatic vessels, along which they grow in continuous lines. Reaching the lymphatic plexus to which the breast in the first instance drains, namely, the fascial plexus lying upon the great pectoral muscle, permeation involves a larger and larger circular area of this plexus, filling up its channels with lines of cancer-cells and sending offshoots

tolerate is unlikely to be effective when it reaches the deeper parts of the breast.

Mode of spread.—*It* is evidently of great importance to surgeons to know in detail how breast cancer spreads. The statistics of diverse methods of operation are an uncertain guide to the ideal method. Here, as in other medical matters, statistics can only occupy a secondary place as supplying confirmatory evidence of conclusions already reached by pathological research.

Some years ago I tried to rationalize operative methods in breast cancer by a careful study of the phenomena of dissemination. The pioneer work of Stiles and Heidenhain had been restricted to the spread of cancer within the limits of the breast itself, and did not produce, even in the minds of those authors themselves, any doubt as to the theory of dissemination then current, namely, the embolic or water-carriage theory. The cancer-cells set loose from the primary growth were imagined to be swept along like driftwood by the lymph- or the blood-stream until arrested in some narrow channel. There can, of course, be *no doubt that such lymph-emboli are the agents which* infect the axillary glands in an early stage of the disease. But a study of the other secondary deposits accessible to observation, viz. those in the skin and bones, shows that these deposits, beginning near the *primary growth, spread in a centrifugal manner from it. This is* illustrated, for bone deposits, in the following table :—

FREQUENCY OF CANCEROUS DEPOSIT OR SPONTANEOUS FRACTURE IN 329 CASES OF MAMMARY CANCER AT THE MIDDLESEX HOSPITAL*

	BONE	NO. OF CASES	PERCENTAGE OF TOTAL
Bones lying wholly or partially within the area liable to subcutaneous nodules	Sternum	30	9·0
	Ribs	28	8·0
	Clavicle	5	1·5
	Spine	12	3·6
	Cranial bones	9	2·7
	Scapula†	1	0·3
	Femur	14	4·2
	Os innominatum†	0	0·0
	Humerus	9	2·7
Bones lying beyond the area liable to subcutaneous nodules	Radius	0	0·0
	Ulna	0	0·0
	Tibia	1‡	0·3
	Fibula	0	0·0
	Patella	1‡	0·3
	Bones of hand	1	0·3
	Bones of foot	0	0·0

Subcutaneous nodules are found to obey the same law. They appear first near the primary growth, and spread from it in a larger and larger circle, but this circle hardly ever spreads below the elbow or below the

* Sampson Handley, *Cancer of the Breast*, 2nd Ed., p. 32

† This bone, owing to its shape, is not much liable to spontaneous fracture, and rarely comes under observation at an autopsy.

‡ Knee ankylosed, femur affected in its whole length, with extension of growth to patella and head of tibia

knee, because the patient dies before it has been able to reach the forearm and the leg. Yet it is in the distal ends of the limbs, above all other places, that the effects of embolism might be anticipated.

These exceptional cases of very extensive centrifugal spread show on a large scale what is occurring to a lesser extent in every case of breast cancer. If long centrifugal strips of the skin and subcutaneous tissues are taken in a direction radiating from the primary growth, there will be found in them, at points near the growth, isolated secondary nodules. Farther out, at a varying distance up to 10 in. from the primary growth, a narrow and elusive zone a few millimetres wide will be found on the



Fig. 295.—Permeation of the pectoral fascia in breast cancer before the breast has become adherent to the fascia. The axillary glands were free from growth. ×85.

A Loose areolar tissue between the breast and the pectoral fascia. B: Pectoral fascia showing darkly-stained permeated lymphatic vessels. C: Pectoral muscle.

deep fascia where its lymphatic vessels are choked by cancer-cells. Beyond this zone only normal tissues will be seen. The zone occurs in each of the radiating strips, and is a section of a large circle which constitutes the true growing edge of the disease. This *microscopic growing edge* may be found at any distance up to 2 ft. from the primary growth, and its detection is the foundation-stone of the permeation theory of dissemination. By permeation is understood the choking up of the lymph-vessels by the growth in continuity of cancer-cells along them.

The facts can only be explained as follows: The immense proliferative pressure of the epithelium at the primary focus forces cancer-cells into the lymphatic vessels, along which they grow in continuous lines. Reaching the lymphatic plexus to which the breast in the first instance drains, namely, the fascial plexus lying upon the great pectoral muscle, permeation involves a larger and larger circular area of this plexus, filling up its channels with lines of cancer-cells and sending offshoots

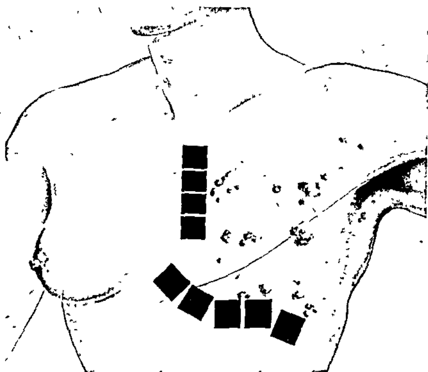


Fig. 296A.—Advanced recurrent breast cancer. Barrage of radium plaques laid down *over apparently normal skin* in the presumed situation of the microscopic growing edge of fascial permeation Plaques removed after a skin-tolerance dose had been given. A gap was intentionally left in the centre of the radium barrage.

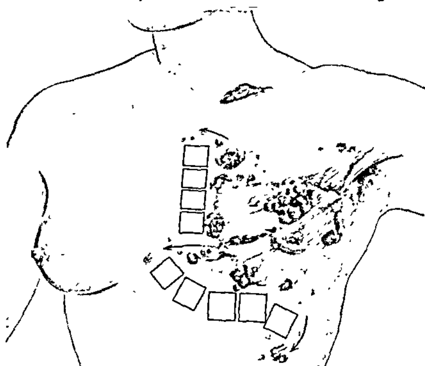


Fig. 296B.—Same case three months later. The positions where the [illegible] The microscopic [illegible] lium barrage, has [illegible] gap intentionally

into the adjoining muscular and cutaneous layers. Sooner or later carcinoma-cells are thus brought into the serous cavities, and rapid visceral dissemination ends the patient's life.

Since the existence of fascial lymphatic vessels has been recently denied, I here insert a photograph (Fig. 295) of permeated lymphatics in the pectoral fascia.

It may be objected that if permeation were so important a process it could not so long have escaped observation. The answer is that it is a fugitive process, the evidence of which is soon obliterated. Permeation of the lymphatic is followed by the curative process to which I have applied the name of perilymphatic fibrosis, which obliterates the lymphatic and destroys the cancer-cells contained in it. The fibrous lymphatic is no longer a permeable vessel, but merely an unrecognizable thread of solid fibrous tissue. Permeation, in its continuous, slow, centrifugal spread, leaves behind it only an almost undetectable network of fibrosed lymphatics or an occasional isolated secondary nodule where the protective process has failed. Breast cancer in its later stages may be conceived of as a gigantic " ringworm " of permeated lymphatics situated in the plane of the deep fascia.

The centrifugal spread of the microscopic growing edge can sometimes be arrested by external radium radiation. In the case of recurrent breast cancer represented in Figs. 296A and B, with the patient's consent and with the co-operation of Prof. Sidney Russ and the late Dr. Helen Chambers, a barrage of radium plaques was laid down *over apparently normal skin* in the presumed situation of the fascial growing edge of permeation. After a suitable dose the radium was removed. A gap was intentionally left in the centre of the radium barrage.

Three months later there was no extension of the nodules, except through this gap and round the ends of the radium barrage. The original position of the radium plaques is indicated by outlines.

For certain forms of cancer, especially lupus and X-ray cancer, I* have demonstrated that the disease arises in areas where for a period of 12 to 50 years there has been local obliteration or blocking of the lymphatic vessels by a lymphangitis of bacterial, viral, chemical or physical origin. Within this area of lymph block, of course, permeation cannot originate, and the disease must spread slowly by infiltration of the tissue interspaces But as soon as infiltration has brought cancer cells into a region where the lymphatic vessels are patent permeation begins, soon to be followed by lymphatic embolism to the nearest glands.

If the region of blocked lymphatics is a very large one, as often occurs in lupus cancer, or cancer originating in a chronic ulcer of the leg, dissemination may be entirely prevented On the other hand the region of lymphatic block may be very small and even microscopic. In such cases, even before the primary growth forms an appreciable lump, permeation and lymphatic embolism may begin.

* *The Genesis and Prevention of Cancer*, by W. Sampson Handley, 2nd ed., 1955, John Murray, London. Macmillan Co., New York.

Operative principles.—The main operative principles deduced from the permeation theory are these :

1. The area which needs widest removal is that in which the growing edge is situated, viz. the deep fascia, for in this layer is found the lymphatic plexus which forms a highway for the spread of the disease beyond the limits of the breast.
2. The area of deep fascia removed must be circular in outline, since permeation spreads with approximate equality in all directions from the primary growth. (Fig. 298.)
3. The primary growth must always be the centre of the area of fascia removed.
4. The skin and muscles being secondarily involved over a smaller area and less widely than the fascia, the removal of a smaller area of these tissues will suffice. The removal of the axillary lymphatic glands in continuity with the primary growth is, of course, essential, since emboli of cancer-cells reach them early along the trunk lymphatics.

Epigastric invasion.—A specially important mode of invasion of the viscera is that which I have described as **epigastric invasion.** It might naturally be expected that permeation would always reach the pleural cavity immediately underlying the primary growth before it penetrated to the remoter peritoneal cavity. But this is not the case. After death, secondary deposits are found in the abdomen alone in 12 per cent. of all cases of breast cancer, the thoracic cavity remaining entirely free from metastasis. The embolic theory fails to account satisfactorily for the failure of the cancerous particles, which upon this theory must have passed through the pulmonary circulation to infect the lungs on their way to the abdomen.

These cases of purely abdominal dissemination are usually caused by the direct infiltration of the abdominal parietes in the epigastric region, just below the ensiform cartilage. This point is the Achilles' heel in the defences of the abdomen against breast cancer, for, when the circle of fascial permeation has spread about an inch beyond the circumference of the mamma, the cancer-filled lymphatics of the *fascial plexus in the middle line, just below the ensiform cartilage,* are separated from the subperitoneal fat only by a single thin layer of fibrous tissue, the linea alba. I have traced all the stages in the invasion of the abdominal cavity at this point, and have shown how the cancer further spreads from the epigastric parietal peritoneum to the adjacent convex surface of the liver, or to the portal glands, and how cancer-cells may *fall through the peritoneal cavity* and give rise to pelvic metastases.

In the operation for breast cancer, no particular attention was formerly paid to the epigastric region and the danger of abdominal invasion was ignored. Yet, as I have shown, the latter may be an earlier and consequently a more important event than thoracic invasion. *In the epigastric region the fascial lymphatic plexus lies* upon, and in, the anterior layer of the rectus sheath, which must be

removed in so far as it comes within the limits of the presumably infected fascial circle.

Contra-indications to operation.—Operation should be refused—

(*a*) When the primary growth has attacked the bony thorax.
(*b*) In the presence of cancer *en cuirasse* or of subcutaneous nodules or skin infiltration situated more than 2 or 3 in. from the primary growth, or of extension to the opposite breast or axilla.
(*c*) If there is a fixed mass of growth in the axilla evidently adherent to its walls.
(*d*) If there is œdema of the arm.
(*e*) If the supraclavicular glands are enlarged, hard, and fixed.
(*f*) If there is evidence of visceral or bone-metastases.
(*g*) If there is incurable constitutional disease, tuberculosis or diabetes for example, likely to be fatal within a short period or to lead to a post-operative fatality.
(*h*) If the growth is of the acute fulminating type.
(*i*) In old age if the growth is of the hard, chronic variety.

In the absence of signs of internal dissemination, certain cases which have passed the limit of operability may still be amenable to treatment by buried radium. A combination of restricted ablation and radiation may be advisable in massive ulcerated and infected growths with limited dissemination. Such cases are not suitable for radium alone in view of the extensive sloughing that would follow.

Examination.—A complete medical examination of the patient should be made before operating. The spine should be examined for angular curvature. Seats of pain, e g. the trochanters, should receive especially careful attention, and an X-ray examination of the thorax is advisable.

Examination for secondary deposits.—A careful examination of the epigastric parietes for subcutaneous nodules—a sure indication that infection of the abdomen has already taken place—should be made, especially if tenderness or pain is complained of in this region. Palpation of the liver must not be omitted. Above all, it must not be forgotten that the first sign of epigastric invasion may be found in the pelvis, from the gravitation into it of cancerous particles. A recto-vaginal examination must be routine, and the presence of pelvic pain, enlargement of the ovaries, or induration in the recto-vaginal pouch should raise a grave suspicion that the disease is inoperable. It should be noted that early secondary cancer of the pelvis does not fix the uterus.

Atrophic scirrhus demands especially careful examination, including an X-ray examination of the pelvis and thorax, for, in spite of the quiescence of the primary growth, dissemination may have progressed far. But if no such insidious spread is found, operation should not be refused. Old age is no contra-indication to operation

in itself, but demands some restriction in its scope. I have operated on a patient over 80 who died more than ten years later of pneumonia without recurrence. Cases presenting enlarged supraclavicular glands, *if the glands are still movable*, should not be denied operation. Though in such cases optimism is misplaced, freedom from recurrence for periods up to ten years or more may be secured if excision of the glands is accompanied by radium treatment. The glands can usually be removed at the same time as the breast. Among 76 cases recorded by Halsted in which three years after operation no recurrence had taken place, there were 9 in which cancerous supraclavicular glands had been removed.

Palliative operations.—It is often justifiable to operate in cases where cure seems beyond the range of hope. Such operations are directed (*a*) to prolong the active and useful period of life and postpone disability, (*b*) to suppress the external manifestations of the disease and relieve the patient of the distress and pain associated with an ulcerated tumour. They are to be recommended only where it seems reasonably probable that no external recurrence will take place before internal deposits, the seeds of which are probably already present, will end the patient's days in a comparatively merciful way. With present-day radiological methods the scope of such palliative operations is much widened, and an additional period of two to five years of activity and freedom from pain may be secured. A patient with extension to the opposite breast and axilla for whom I performed a bilateral operation, removing both breasts and the axillary glands of both sides in one continuous mass, did active work as a laundress for two years afterwards. Another patient, the mother of a young family, was refused operation by the surgeon whom she first consulted. She accepted my offer of a sporting chance, and subsequently did five years' active house-work before she succumbed to thoracic deposits. There was no external recurrence.

Technical Variations in the Mode of Operation

It is obvious that there are many different ways of attaining the object defined on p. 717 as the removal intact of the permeated area of lymphatics which surrounds the primary growth, and of the embolically invaded glands. Any variation of method which does not violate the canons of pathology may be adopted in order to secure some particular advantage, or merely at the personal preference of the operator

Methods in which dissection of the axilla precedes removal of the breast.—There is something to be said in favour of clearing the axilla before the breast is ablated. As Gross pointed out, the axillary tissues may be found so involved in growth that their removal is impracticable. This is discovered at once, before the operator has gone too far to turn back. It is in such cases that the method finds its best application. They are usually recognizable beforehand as

doubtfully operable cases. If the axillary glands are partly fixed or unusually large, the axilla should be explored as the first step of the operation, and the Rodman method may be conveniently adopted. Rodman believed that by early division of the axillary lymphatics the risk of "expressing cancer-cells into adjacent and even possibly remote tissues" could be avoided. It seems, however, just as likely that early division of the lymphatic trunks will increase the risk of implantation of cancer-cells in the wound. Another advantage claimed for the operation is that the breast is left as a warm covering for the thorax until the operation is nearly complete. This end can be just as well secured by relays of hot towels. It was further claimed by Rodman that hæmorrhage is very much less when the branches of the axillary artery are exposed early and ligated at their origin. It is equally easy to secure them before they are divided in the ordinary operation. The most troublesome source of bleeding, namely, the perforating branches of the internal mammary artery, is left to be dealt with later. Personally, believing that the delimitation of the anterior half of the infected circle of deep fascia can be more certainly and deliberately done before the axilla is opened, and that this is a most important step of the operation, I have not adopted any of the "axilla-first" methods. I have not found that the "breast-first" method involves serious bleeding, unless the mistake is made of using a stimulating anæsthetic.

Rodman's operation.—The axilla-first method is said to have been first practised by Meyer. It was advocated also by Kocher and by Rodman, and recently by Sir Cecil Wakeley.* The method violates none of the canons of pathology and constitutes a technical variation in operative procedure which appeals to some surgeons. A full description will be found in the late Professor Rodman's work on diseases of the breast.† (A sufficient quotation from that book appeared in the third edition of "Modern Operative Surgery", p. 610 *et seq.*)

Handley's Method of Operation

The operation now to be described appears applicable to almost any case that presents itself with clinical signs of mammary carcinoma. Even if the case be an early one, without obvious enlargement of the axillary glands, the scope of the operation should not be restricted if the patient is vigorous. But in feeble old people a more limited operation should in any case be practised to minimize the immediate risk.

My method has been arrived at by a critical study of the procedures of various operators in the light of my own studies of dissemination. The operation first described by Stiles and Cheyne has stood this test better than any other, and with some modifications, and with the addition of routine removal of the sternal part of the great pectoral (Halsted), forms the basis of the method.

* *Brit Med Journ*, Oct. 2, 1948.
† "Diseases of the Breast," Philadelphia, 1908.

The operation is not put forward as the only method of removing a breast cancer. Any number of technical variations are possible, but these should all be tested by the pathological criteria now available.

Preparation of the patient.—A purgative should be given 36 hours before the operation. A purgative the night before the operation is undesirable, as it tends to deplete the patient's fluids. If the patient is tired or nervous, or if the heart is flabby, a few days' rest in bed and small doses of strychnine are advisable.

The axilla should be shaved the night before operation, and as a septic area it should be scrubbed with ether soap and then with acetone and 5 per cent. spirituous mercurochrome. Scrubbing of the breast itself is to be avoided as tending to massage cancer-cells along its lymphatics. The breast area is simply painted with the mercurochrome solution the night before, and covered up with sterile gauze until the time of operation, when it is again painted The area sterilized should in every direction considerably overlap the area of operation.

During the operation the arm should be held by an assistant abducted to rather more than a right angle It should not be stretched upwards, for forcible elevation may cause subsequent neuralgia from stretching of the brachial plexus. I have even seen one case where brachial palsy was thus produced

The patient should lie close to the edge of the table on the side of the operator. The assistant stands on the opposite side.

Choice of anæsthetic.—The anæsthetic for a radical breast operation should fulfil the following conditions:—

1. It should not excite the circulation and so increase bleeding. In this respect chloroform given by the old mask and drop-bottle method was ideal from the surgeon's point of view, but anæsthetists unfamiliar with the method cannot be pressed to adopt it. Ether by the closed method causes maximal circulatory stimulation. Morphia gr. $\frac{1}{4}$ or omnopon gr. $\frac{1}{3}$ given half an hour before operation helps to prevent circulatory excitement.
2. It should not be accompanied in any stage of the operation by the smallest degree of respiratory obstruction. The ideal is quiet, regular, almost inaudible respiration, this is helped by the occasional administration of a gentle stream of oxygen. Maintenance of a clear airway is essential. Cyanosis increases venous bleeding and may lead to pulmonary complications during convalescence.
3. The anæsthesia should not be too deep. Consciousness should return within a few minutes of the end of the operation.

Improvements in anæsthetic methods during the last few years have given to the anæsthetist a status almost independent of the surgeon. The fulfilment of the foregoing requirements and the choice of

anæsthetic are the responsibility of the anæsthetist and need not be further considered here. The combination of an intravenous anæsthetic with subsequent gas and oxygen administration, supplemented if required by an occasional whiff of ether, seems to be a popular method.

Centring of the operation.—The centre of the growth, not necessarily the nipple, must be taken as the central point of the operation. The

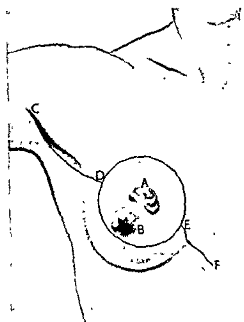


Fig. 297.—Handley's operation for breast cancer. The incision.

D E is the possibly infected area of skin, 4–5 in. in diameter, which requires ablation; it is centred upon the growth A, not upon the nipple B. D C is

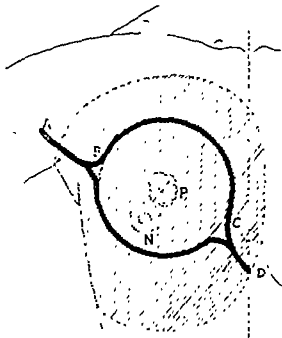


Fig. 298.—Area of fascia removed in Handley's operation for breast cancer.

N, nipple P, primary growth.

(Handley's "Cancer of the Breast")

operator is not doing an "amputation of the breast,"—his aim, it may be repeated, is the removal in one piece, enclosed in a sheath of normal tissue, of (1) the permeated area of the lymphatic system which surrounds the primary growth, and (2) the lymphatic glands which may have been embolically invaded by the disease. The permeated area of the lymphatic system may extend considerably beyond the limits of the breast.

Skin incision.—The skin incision is only just deep enough to open up the subcutaneous fat without extending through it into the neighbourhood of the deep fascia. It consists of three parts:

(1) A *ring incision*, as first practised by Mitchell Banks, 4 or 5 in. in diameter, accurately centred on the growth, and surrounding it at a safe distance, slightly tailing off into (2) above and into (3) below.

It is a good practice before beginning the operation to mark out by a scratch-mark the circle of dangerous skin which requires removal. Here it may be remarked that local recurrence in the form of subcutaneous nodules near the scar, formerly so common and now so rare, which used to be attributed to removal of too small an area of skin, is usually due either to removal of too small a circle of deep fascia, or to the inclusion of patches of deep fascia on the deep aspect of the flaps.

(2) A *curvilinear incision* giving access to the axilla. The axilla is opened by turning forward a rudimentary flap consisting of skin and a thin layer of subcutaneous fat, whose base lies along the anterior axillary fold. The axillary incision begins at the lower edge of the great pectoral, close to its insertion. It ends, also, at the lower edge of the great pectoral, by joining the annular incision (1). It crosses the base of the axilla, and its convexity reaches back about an inch towards the axillary vault. It affords perfect access to the axilla, and good drainage afterwards. Incisions following the lower edge of the great pectoral muscle are likely to result in a bridle-scar which limits the movements of the arm.

(3) A *linear incision* coming off from the lower and inner part of the annular incision and passing downwards for about 2 in. towards the tip of the ensiform cartilage. Its object is to give access for the removal of the deep fascia over the upper part of the abdominal wall. Without it this important step in the operation cannot be properly carried out. (Fig. 297.)

Elevation of the anterior skin-flap.—The anterior skin-flap is next undermined in the midplane of the subcutaneous fat (Fig. 299), until a semi-circular area of the deeper subcutaneous fat, 10 to 12 inches in diameter, with the primary growth at its centre, is exposed The exact anatomical limits of this dissection will, of course, vary with the situation of the growth in the breast. The assistant retracts the skin-flap as it is formed, and subsequently keeps it carefully wrapped in hot towels, frequently renewed, or in large dry swabs, hot from the sterilizer (Riddell). Neglect of this precaution is likely to be followed by severe shock, and later by ulceration of the edges of the flaps. At the upper and lower angles of the incision small areas of the posterior flap should also be undermined at this stage, so as to expose fully the base of the axilla and the region of the epigastrium. Great care must be taken not to expose or intrude upon the deep fascia, and not to score the flaps

At this period of the operation no attempt should be made to apply artery forceps to every small bleeding-point. Spouting vessels in the deep surface of the skin-flap should be clamped, but bleeding from the exposed surface of subcutaneous fat is sufficiently checked by the pressure of large flat swabs, for nearly all the exposed vessels will again be divided at a deeper level It is often useful to tuck sponges beneath the flaps as these are formed.

Delimitation of anterior half of the area of deep fascia to be removed.—A semi-circular incision is now carried down to the muscles through the deeper subcutaneous fat close to the base of the anterior skin-flap, which is meanwhile strongly retracted by the assistant.

Elevation of deep fascia from the underlying muscles.—The semi-circular area of deeper subcutaneous fat and deep fascia, in which lies

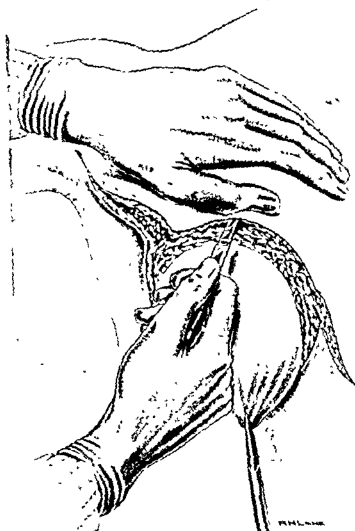


Fig. 299.—Elevation of the anterior skin-flap by subcutaneous transfixion.

An assistant meantime, with a pair of artery forceps, pulls the breast in a direction indicated at each moment by the direction of the handle of the operator's knife. The knife keeps to the midplane of the subcutaneous fat. In thin subjects, or if the operator is inexpert, the flaps should be raised by ordinary dissection.

embedded the presumably permeated area of the fascial-lymphatic plexus, is now dissected from the subjacent muscles for some distance from its circumference towards its centre, so as to form a wide marginal fringe of the main mass, consisting of breast, pectoral muscles, and axillary contents, which is subsequently to be removed. The fringe of deep fascia is to be raised up all round the base of the anterior flap

until the knife reaches either the margin of the great pectoral muscle, the margin of the axillary outlet, or the edge of the breast, as the case may be. (Fig. 300.)

The amount of dissection required varies in different parts of the field of operation. At the upper limit of the field the fascia must be dissected off the clavicular portion of the great pectoral if it has

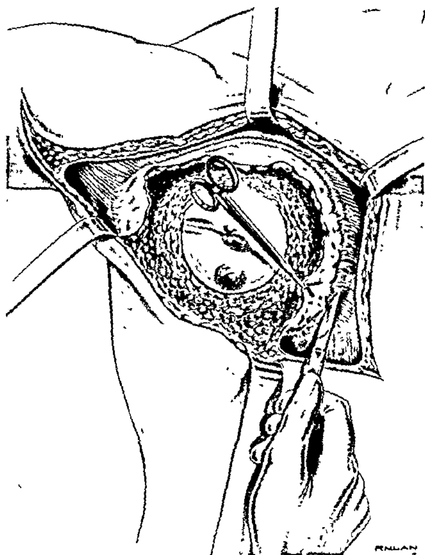


Fig. 300.—Elevation of deep fascia.

The thin anterior skin-flap has been raised so as to expose the anterior half of a circle of the deeper subcutaneous fat, 10 to 12 in. in diameter. This semicircle has been circumscribed by a ring incision passing down through the deep fascia. The included area of deep fascia, containing the growing edge of the disease, is now being raised all round from the muscles.

been decided to retain the clavicular fibres of this muscle; otherwise in this region the fascia will come away with the great pectoral when that muscle is divided at its clavicular origin, and very little freeing of it will be requisite. Towards the middle line it will usually require dissecting up from the sternum, and, in growths of the inner margin

of the breast, from the inner margin of the opposite great pectoral muscle. In such cases the surgeon may divide, and must secure, the perforating branches of the internal mammary artery on the side opposite to the growth. The corresponding perforating branches on the same side as the growth are divided later, during the detachment of the great pectoral.

At the lower limit of the field of operation, a 10-in. circle of deep fascia with the growth at its centre will usually extend well down

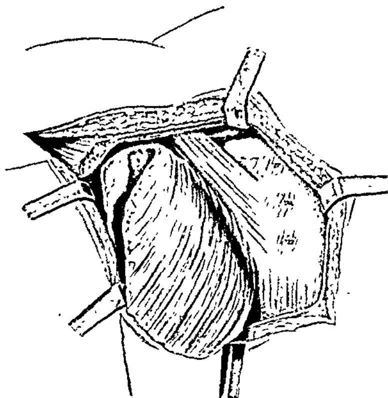


Fig. 301.—Reflection of pectoralis major.

The deep fascia and the upper part of the anterior layer of the *rectus sheath* have been raised as far as the edges of the great pectoral. This muscle has been divided at its origins and its *insertion*, the perforating intercostals have been tied, and the breast turned over towards the axilla.

over the epigastric region of the abdomen. In this part of the field the anterior layer of the rectus sheath, on both sides of the middle line, should be raised up and removed with the deep fascia. To accomplish this, the linea alba must be split from below upwards in the coronal plane. In the epigastric region wide and careful removal of the deep fascia is imperative, so as to prevent the access of cancer-cells to the peritoneal cavity. In this part of the field, numerous small blood-vessels emerging from the rectus muscle will probably need attention.

Division of muscles.—It is usually safe to leave the clavicular part of the pectoralis major (Fig. 301). It is first split close to its clavicular attachment, a finger is inserted beneath the muscle from above, so as to put its fibres on the stretch, and its chondral and

sternal attachments are rapidly divided from above downwards close to their origin.

It is best to scrape through rather than cut the origin of the great pectoral from the sternum and costal cartilages. In this way the perforating intercostal branches are seen and caught in turn, each with two pairs of forceps, before they are divided. Much bleeding

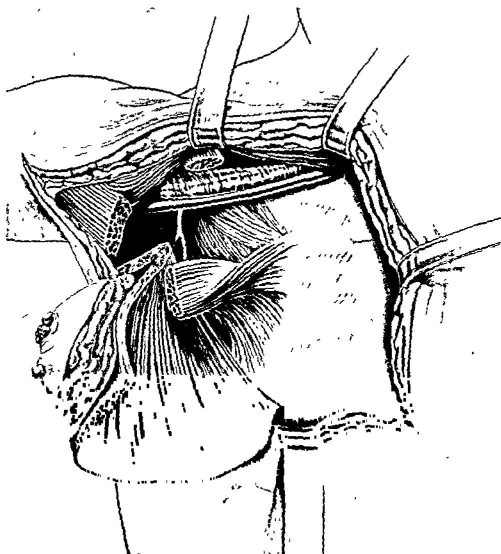


Fig. 302.—*Reflection of pectoralis minor.*

The exposed lesser pectoral muscle has been divided at its insertion, and, beginning at the very apex of the axilla close to the clavicle, where the subclavicular glands are situated, the axillary fat and glands have been stripped downwards from the axillary vein, which is now exposed

is thus saved and the risk of troublesome retraction of the divided arteries is avoided. Should this arise, and if the end of the artery cannot be found, the invisible bleeding-point must be underrun by a suture introduced deeply into the intercostal space with a small semicircular needle The muscle is lifted from the chest and turned outwards, and the external anterior thoracic nerve and the vessels

which run with it are divided where they pierce the costo-coracoid membrane.

The pectoralis minor now comes into view, and is best removed, for two reasons. If its nerve is injured during clearance of the axilla a strong fibrotic band replaces the muscle and restricts movement. Also the muscle hinders complete clearance of the axilla. Rosenquist of Stockholm in 1,014 cases found 11 of axillary recurrence. In every one of these cases the pectoralis minor had been left. It is divided at its costal origin by scraping movements of the knife which allow vessels to be seen and secured before they are cut.

The pectoral muscles are then cut across at their insertion respectively into the humerus and the coracoid process, and the whole mass of tissue is allowed to fall over towards the axilla. (Fig. 302.)

Removal of axillary contents.—The costo-coracoid membrane, now freely exposed, is cautiously divided just below the clavicle, and the fat at the extreme apex of the axilla is thus brought into view. It now becomes easy to reach the highest axillary glands—subclavian in the strict sense of the word—which so easily escape notice unless they are carefully looked for. The clearing of the axilla should be begun at the very apex of the space, hard by the clavicle. The fat in this situation is swept downwards with gauze, exposing a short length of the vein, internal to which a lymphatic cord, sometimes indurated, will be found running upwards into the posterior triangle. This should be seized with dissecting forceps and broken off as high as possible Downward sweeps of the gauze now expose several tributaries of the axillary vessels, which are caught and then divided On the inner wall is seen the first digitation of the serratus magnus, which is cleared until the external respiratory nerve of Bell comes into view lying upon it

The next step is one which may be described as the key to the quick and complete clearing of the axilla, or so at least I have found it. As soon as the nerve of Bell is seen, a closed pair of dissecting forceps is pushed directly backwards through the tissues just external to it, and right through the fascia covering the subscapularis muscle, until the red fibres of that muscle are exposed. The point of the forceps is moved outwards, and a piece of gauze, introduced into the interval thus made, sweeps all the tissues of the axilla outwards. This manœuvre exposes the intercosto-humeral nerve, which is injected with alcohol and then divided Similar treatment should be meted out to the lateral cutaneous branch of the third intercostal nerve, which lies a space below. The long subscapular nerve which lay just external to the forceps is at the same time placed on the stretch, and can be cleared with gauze from above downwards. This exposes the subscapular vessels, several branches of which will require ligation.

The upper half of the axillary vein is now exposed, but the lower half is still covered by a definite fascial layer lying behind the tendon of the great pectoral. This layer is freely divided either on a director

or, if practice justifies boldness, by a direct knife-cut in the line of the vein. A small artery is constantly found in this layer of fascia.

The remainder of the serratus magnus is now cleared by bold gauze dissection backwards, or, if the proximity of the growth makes it necessary, a superficial layer of the muscle is removed by the knife. Either process stops just in front of the nerve of Bell, which should be carefully preserved. If the muscular surface has been shaved off, the fibres of the elevated portion are cut across just in front of and parallel with the nerve. The fatty tissue of the lower axilla is thus reached again, and the process of sweeping outwards with gauze is resumed until the edge of the latissimus dorsi comes into view. The surface of this muscle is cleared with a knife as far as is necessary to secure the desired circle of fascia concentric with the primary growth This part of the dissection varies much in extent, according to the situation of the growth.

Reflection of the posterior skin-flap.—It will be noted that up to this point the posterior skin-flap has not been reflected The raising of the anterior skin-flap is, next to the incision, the first step of the operation, the raising of the posterior skin-flap should be the last. The skin composing this flap is not very well vascularized, and its circulation and vitality should be kept intact as long as possible for fear of chill and subsequent ulceration. Though it has not been raised, the posterior skin-flap, still attached to its deep fascia, has been undermined to the full extent of the 10-in. circle of fascia which is to be removed The ablation is completed as follows. The hanging breast is replaced in position on the thorax. The assistant draws it inwards and places the tissues on the stretch while the operator raises the flap by dissection from before backwards, carefully avoiding scoring the flap or exposure of the deep fascia. The breast is now attached only by the posterior half of the 10-in circle of fascia and only along the circumference of this circle. While the assistant retracts the posterior flap the operator draws the mass of tissue outwards and divides, as far back as possible, along the base of the posterior flap, the thin membranous layer of deep fascia, thus completing easily and with certainty the removal of the desired circular area of deep fascia, and of the breast.

If the operation is performed systematically it will not be found necessary to do any "pecking" and minor dissection afterwards in the axillary region Search should be made, however, for hard glands along the upper part of the brachial artery.

If an adequate supply of artery forceps is available, say two dozen, few vessels have hitherto been tied. The ligation of the vessels is the next step, and I have always used very fine silk, 000 Japanese, or fine linen thread, boiled and then soaked in 1.1000 watery flavine. Catgut has less frictional grip, and for this and other reasons is not so safe.

The whole field of operation is now mopped carefully, with a

pushing, not a rubbing movement, and the smallest oozing-points are ligated.

In order to wash away any loose cancer-cells and prevent implantation, the wound is irrigated copiously with 2 to 4 pints of 1-in-2,000 perchloride of mercury at a temperature not exceeding 102°. The mercury will presumably coagulate any isolated cancer-cells. The wound is now flushed with warm saline to get rid of the mercurial solution which might damage the surface of the radium tubes.

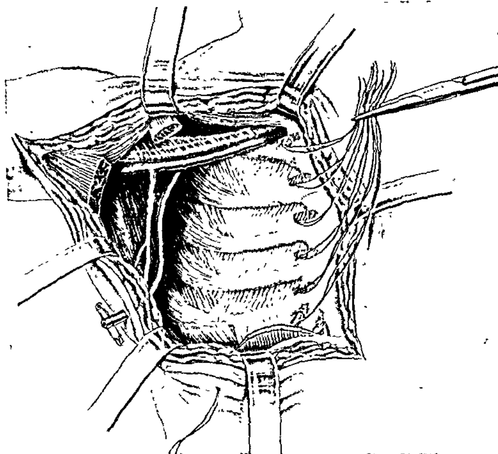


Fig. 303.—Insertion of radium tubes.

The breast has been removed, the radium tubes have been placed in position, and the drainage-tube has been inserted.

Introduction of radium tubes (Fig. 303).—Up to this point in the operation nothing has been done to sterilize the internal mammary lymphatic chain, shown by R. S. Handley and A. C. Thackray to be already invaded in 33 per cent. of clinically operable cases. It has yet to be proved that post-operative X-ray treatment is competent to eliminate this danger, and in my opinion radium radiation by buried tubes of the *whole length* of the chain, up to the supraclavicular glands and down to the epigastric angle, should precede the closure of the wound (Fig. 303). Each tube of 2 mg. RaEl. is threaded on stout fishing gut or silk. The two ends are knotted together. No knot is

made near the tube, for alternate pulls on each thread of the pair facilitate removal by drawing open the track in which the threads lie. The ends of the threads are brought out either through the line of the incision or through separate punctures at points from which a nearly direct pull on the tubes can be exerted. Safety pins are attached to them. The tubes are removed after five days, usually under a brief anæsthetic. They should not have needle-sharp points, and the eye of the tube should be close to its base, so that in removal it cannot jam across its track. Their positions are as follows:—

Tube 1.	Through a separate puncture in the neck, penetrating the deep fascia, at the lower and inner angle of the posterior triangle, a tube is passed downwards and inwards in a direction bisecting this angle. It lies behind the head of the clavicle. It is here that the first enlarged supraclavicular gland appears.
Tube 2.	Through the same puncture a tube is passed directly upwards along the lower deep cervical glands. It lies outside the internal jugular vein.
Tube 3.	Again through the same puncture a long 8-mg. tube is passed directly outwards. It lies just above and parallel with the clavicle along the lymphatic chain which accompanies the transverse cervical artery.
Tube 4.	Through the axillary wound at the apex of the axilla a tube is introduced upwards and inwards above the first rib, just internal to the axillary vein, in the situation of the main lymphatic duct.
Tubes 5–9.	At the inner ends of spaces 1–5 inclusive, in the substance of the intercostal muscles, tubes are introduced, one in each space, their points just passing behind the edge of the sternum (The wide second space may require two tubes, and if the sixth space is not too narrow a supplementary tube may be used for it)
Tube 10.	Through a separate puncture over the epigastric angle a tube is pushed upwards close behind the sternum to lie between the xiphoid cartilage and the costal margin This tube should be omitted if the operator fears he may puncture the pericardium.

Precision radiation.—Radiation should be controlled by detailed knowledge of the mode of spread of the disease, and applied along the known lines and planes of its spread. Radiologists at present are too exclusively governed by the crude conception of mass-radiation; of uniform radiation of the mass of normal tissues which includes the growth and its extensions. *In the use of X-rays it may* be that this conception, though it involves the undesirable radiation of much normal tissue, cannot be transcended, and to a large extent the same

statement applies to the surface application of radium. However, implanted radium tubes can be inserted with the utmost precision along the known lines and planes of lymphatic spread so as to maximize their effect on neoplastic tissue while minimizing their undesirable action on normal tissue. In this field the pathologist-anatomist-surgeon cannot hand over his responsibilities to the radiologist, he

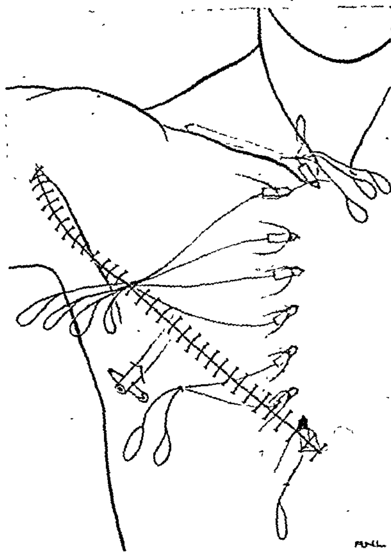


Fig 304.—The radium tubes in position and the incision sutured. The ends of the silk attached to the radium tubes are seen hanging out of the incision. The positions of the buried tubes are indicated.

must himself become a radio-surgeon. (Fig. 304.) A drainage-tube about the size of a No. 8 catheter is introduced posteriorly through a stab-wound at the base of the posterior flap. Search is made that no swab is left behind, and the wound is then closed.

Sutures.—Trial is made how best the incision may be brought together. The problem varies in each case according to the situation of the growth in the breast and to the degree of laxity of the skin.

The most striking indirect advantage of the wide fascial removal now becomes evident. This wide removal of the deep fascia so mobilizes and frees the surrounding skin that, even after the removal of a 5-in. circle of integument, the edges of the incision can usually be brought together without the use of tension stitches, by a single continuous suture of fine catgut or silk, or by metal clips. Tension in the skin-flaps—the principal cause of prolonged shock, of pain and discomfort to the patient, of impaired circulation in the skin-flaps, and of delayed union and ulceration in the sutured incision—is thus generally avoided. (Fig. 304.)

Often it will be found best to bring the edges together in triradiate fashion, in other cases as a sinuous line. In growths of the upper and outer quadrant some difficulty may be encountered in covering the raw area, and in these cases the axillary flap of skin may be pulled inwards to assist in covering the thoracic gap. It is rare to meet with a case in which it is impossible to bring the edges of the incision together, but this may happen in thin women with very small breasts and an ill-developed thorax—especially if, on account of skin-adhesion, it has been necessary to remove an unusually large circle of the integument. In all cases where tension of the flaps is threatened, immediate skin-grafting by the Thiersch method should be done, and is most satisfactory in its results.

Alternative method of fashioning the skin-flaps.—After the ring incision has been made, but before the axillary and epigastric incisions have been marked out, the tedious process of dissecting up the anterior skin-flap may be quickened by the following manœuvre: A sharp-pointed narrow knife with a blade 3 in. long is pushed into the mid-plane of the subcutaneous fat from some convenient point in the ring incision in a direction radially away from the growth, so that the flat of the blade lies parallel with the skin surface. The left hand is now placed flat upon the skin surface, and the assistant pulls the breast over in the direction towards which the handle of the knife is pointing, so as to render the tissues tense. With a sawing movement the knife is now rapidly carried subcutaneously round the anterior half of the ring incision, splitting the subcutaneous fat into two layers. The operation is completed in the usual manner. Great care is necessary to prevent the point of the knife from coming too near the skin surface and thus scoring the skin-flap and imperilling its nutrition, and in spite of the saving of time which it secures, I hesitate to recommend "*subcutaneous transfixion*" as a routine method, though, except in thin subjects, I always use it myself for the anterior flap. It should be used when there is a fairly thick layer of subcutaneous fat, and when the operator is confident that he can avoid scoring the flaps with the point of the knife or leaving on their deep aspect dangerous islets of deep fascia. (*See* Fig. 299.)

Initial raising of the posterior flap.—Mr. Victor Riddell* prefers

* *British Journal of Surgery*, October, 1948, xxxvi, 142.

to raise the posterior flap immediately after making the incision, and next to raise the upper part of the anterior flap, thus gaining sufficient access to divide the pectorals and clear the axilla. He seeks for and controls the branches of the acromio-thoracic artery before dividing the lesser pectoral, and dissects the axilla from below upwards, securing the tributaries of the axillary vein as he proceeds. In my opinion it is much easier to expose the axillary vein at the apex of the axilla and to sweep the tissues downwards by gauze dissection. All the tributaries of the vein come easily into view and can be secured before they are cut. Mr. Riddell says:—

> "There are certain advantages in delaying the elevation of the medial flap. . . . Elevation of the medial flap involves division of branches and tributaries of the internal mammary vessels in three separate situations: first when the initial incision is made into the subcutaneous tissues, again as the base of the flap is approached, and again when the pectoral muscles are removed."

He claims that bleeding is reduced, time saved, and the vitality of the flap preserved to the end of the operation. In my opinion Riddell is wrong in favouring the anterior flap at the expense of the worse nourished posterior flap, indeed he gives an illustration of a case of sloughing of the margin of the posterior flap. That is why I prefer to raise the anterior flap first. Little loss of blood occurs if the assistant makes pressure with the flat of his hands on the undermined area, rapidly seizes a few bleeding points on the exposed subcutaneous tissue, and tucks swabs under the flap when the surgeon has fashioned it. If the fibres of the great pectoral are *scraped* by the knife away from their attachments to the sternum and costal cartilages the perforating branches of the internal mammary are exposed intact and can be seized individually by two pairs of forceps and divided between them. Therefore I cannot agree that the Riddell operation lessens hæmorrhage, which is its main claim to adoption. Nevertheless his careful paper with its meticulous attention to detail is worthy of the study of all interested in the subject, and he has performed 170 radical operations without a death.

Alcohol injection of nerves.—The operation is often followed by persistent neuralgia down the back of the upper arm in the distribution of the intercosto-humeral nerve. I find that this sequela can be prevented if, when the intercosto-humeral nerve and the lateral cutaneous branch of the third intercostal nerve are exposed in the stripping of the inner wall of the axilla, these nerves—before they are divided—are injected with a few minims of absolute alcohol. The procedure only takes a few seconds and is well worth doing.

Constitutional effects of the operation.—The operation for mammary cancer inevitably produces some degree of immediate shock but the patient usually leaves the theatre with a pulse of about 80, and of

fair volume. I have very rarely, however, seen dangerous shock during the operation. For its prevention it is, I believe, important to keep the skin-flaps, and the thorax generally, covered with hot towels so far as the operator's convenience will allow. The persistence of shock for some days appears to depend almost entirely on chill during the operation and upon tension in the skin-flaps, and the pain associated therewith. At any rate, I have noticed, paradoxical as it may appear, that the shock of the operation just described passes off much more quickly than the shock which follows the less extensive operations described in the earlier textbooks, in which tension sutures are necessary for the approximation of the skin-edges. Recovery is rapid, and pain usually ceases within twenty-four hours.

After-treatment.—If hæmostasis has been carefully attended to the many-tailed bandage may be applied rather loosely. A tight chest bandage is uncomfortable and even dangerous. It is also harmful to the nutrition of the flaps.

The arm is not included in the chest-bandage, but is placed in a separate sling, which is then attached by a safety-pin to the chest-bandage beneath. Discomfort is thus avoided while the necessary restriction of movement is secured. Abduction at the shoulder is not allowed until after the stitches are removed, for it stretches the flaps and so hinders their nutrition. One injection of morphia or $\frac{1}{12}$ grain of heroin may be necessary on the night of the operation Feeble subjects may be given a mixture containing small doses of digitalis and brandy for a few days. If there is any history of or tendency towards bronchitis, the patient should be placed in a semi-sitting posture from the evening of the day of operation. A daily injection of transpulmin for three days helps to prevent lung complications. The dressing is changed, and the drainage-tube removed or shortened, after twenty-four hours The drainage-tube should never be retained beyond forty-eight hours. The patient usually gets up on the fifth day, or as soon afterwards as she experiences a desire to do so. Rough nursing or voluntary movements of the arm before the wound is healed are apt to be followed by the collection of serum beneath the flaps, or by gaping of the edges of the wound. A serous collection is also likely to require evacuation from beneath the flaps in the epigastric region if the bandages are allowed to become too loose Stitches should not be removed too early, and when they are taken out, if there seems any risk of gaping, a series of collodion strips should be placed across the wound. *Gentle nursing and minimal movement are essential to the smooth convalescence of these cases.* The patient is usually able to leave the hospital or nursing home in fourteen to twenty-one days. After the end of the third week, systematic measures may be necessary to mobilize the scar upon the chest Massage in the ordinary sense should be avoided. Passive and active movements of the shoulder joint, and rocking the skin upon the ribs will do all that is necessary for the recovery of full movement.

I invariably recommend a short course of deep X-ray treatment as a prophylactic against recurrence after the operation. It is, I think, doubtful whether an extended course is advisable, but after an interval of from three to six months the course may be repeated.

Difficulties of the operation.—*Hæmorrhage* may be troublesome especially in the young and full-blooded, and for this reason the operation should not be done in the immediate pre-menstrual period. It is important to reduce all bleeding to a minimum in order to prevent shock and collapse, and the operator, the anæsthetist and the assistant (the latter, by the deft use of hand- and swab-pressure), all share this responsibility. I have very rarely found transfusion necessary, either during or after operation.

Adiposity, while it increases the actual amount of cutting, really facilitates the operation. It renders easier the elevation of the flaps, without risk of including in them the dangerous deep fascia, and facilitates, by providing plenty of "slack", the subsequent closure of the

the

tissue and with an ill-developed thorax. In these patients the flaps are necessarily thin, ill-nourished, and apt, unless great care be taken, to contain patches of deep fascia. There is no such reserve of skin as a fat person possesses, and skin-grafting is more likely to be necessary. The flaps, unless extra care be taken, are more likely to be affected by chill during the operation.

Peripheral position of the tumour.—The operation is easiest when the growth lies under the nipple, and is especially troublesome when the growth is at the axillary margin.

Adhesion of infiltrated glands to the vein—This difficulty must be dealt with boldly by exposing the vein above and below the adherent mass, clamping it in both situations, resecting the vein and the adherent mass, and tying off the ends of the vein, not forgetting to tighten the first hitch of the knot *after* the forceps have been taken off. It is very unsafe to ligature the vein first and then to resect it. If this is done, the ligatures are likely to slip.

Resection of the axillary vein is not followed by any serious consequences.

Envelopment of the axillary artery by growth.—If detected in time, this should lead to the abandonment of the operation. In one case in which I accidentally wounded an axillary artery, much displaced and surrounded by growth, and in which both the artery and the vein were resected, neither failure of nutrition nor paralysis followed. The artery was much reduced in calibre by the constriction of the growth, and probably a good collateral circulation was already present. In a second case I deliberately resected the artery and vein without any impairment of the use of the arm.

Retraction of a divided perforating intercostal artery.—I have already said that these arteries should be seen and clamped before they are divided. If cut short or torn across, the bleeding vessel may retract between the intercostal muscles. The application of forceps is then difficult or impossible, and the artery must be secured by under-running. The ligature, threaded in a small semicircular needle, is passed deeply into the intercostal space, first on one side of the bleeding-point and then on the other. It is then tied rather tightly. I have never found it necessary to expose and tie the internal mammary artery.

Avulsion of tributaries of the axillary vein.—In old people the veins are very friable, and any undue pulling during the axillary dissection may tear away a tributary of the axillary vein, leaving a hole in the main vein. The bleeding-point should be seized and tied in the usual way, even though considerable narrowing results. It is rarely necessary to ligature the axillary vein above and below.

Adhesion of glands to nerves.—Any nerve in the axilla to which a gland is firmly adherent should be resected with the gland, and the nerve-ends, if possible, sutured together. Firm adhesion to the brachial plexus or its main branches involves the abandonment of the operation, and is only seen when there is diffuse infection of the axilla.

Pneumothorax.—It is very easy in patients with atrophied intercostal muscles to puncture the pleura with the point of an artery forceps while seizing a divided perforating intercostal artery. The accident need not occasion much anxiety. If the puncture cannot be closed by a stitch, the assistant should press a swab over it until the end of the operation, when the flaps are brought together over it. On one occasion I punctured the pleura while introducing a radium tube into an intercostal space. A considerable amount of air entered, and this patient suffered from distressed breathing and some amount of shock for several days.

Difficulty in closing the wound.—Formerly surgeons experienced great difficulty in closing the wound after the operation for breast cancer. Deep tension sutures were inserted and the flaps forcibly approximated. In consequence, the patients suffered great pain and shock, persisting for days after the operation. The difficulty arose from the restricted scope of the operation then practised. Undermining of the flaps was not understood, and the adjoining skin was therefore not mobilized.

A similar difficulty arises when very large areas of skin are ablated, and thus in Halsted's operation no attempt is made to bring the flaps together, and the operation is terminated by immediate skin-grafting of the raw area.

I have shown that it is sufficient to remove a moderate amount of skin, and that extensive undermining of the flaps is a necessary step to the complete removal of the disease. Recognition of these two facts has removed the surgeon's difficulties in closing the wound.

Skin-grafting.—Skin-grafting should be done by Thiersch's method, and at the time of operation. The grafts then almost invariably

"take" well. They are to be obtained from the front of the patient's thigh. Grafting is usually necessary in carcinoma of the male breast. In sarcoma of the breast also, owing to extensive skin-adhesion and the amount of skin that has to be removed, it is generally unavoidable.

To ensure satisfactory healing after skin-grafting, it is necessary that the flaps should be induced to adhere to the deeper tissues all round the grafted area, in spite of the "slide" produced by the respiratory movements. It is further necessary that the axillary cavity should be completely closed and shut off from the thoracic wound. The first object is promoted by snicking the edge of the flap all round by radiating cuts ½ in. long at intervals of ⅓ in., a step which also increases the length of the coast-line from which epithelium may spread over the grafted area if any of the grafts fail. The edges of the flaps are then sewn down to the intercostal muscles at intervals by interrupted sutures (Halsted), before the grafts are applied. The closure of the axilla is secured, at the point where that cavity is coterminous with the grafted area, by a stitch taking up first the edge of one flap, then the exposed surface of the intercostal muscles, then the edge of the other flap. This stitch is essential to the proper closure and rapid healing of a grafted wound. If the axilla *cannot* be closed, skin-grafts must be applied to the whole of its vault, and Halsted recommended this as a routine method. In skin-grafted cases it is especially important to observe a rule which applies to all radical operations, namely, that during the first few days nursing manipulation should be reduced to a minimum, that *two* nurses must assist when the patient is moved, and that the patient should be rolled, not sat up in bed. The grafted area should not be dressed until the fifth day. The grafts should be subsequently exposed to the air, covered only by a wire-gauze cage, over which a single layer of gauze is thrown. If crusts begin to form on the grafted area periods of hot fomentation should alternate with periods of exposure.

The Diathermy Operation for Breast Cancer

In the last edition of this book I described in detail the performance of the radical operation by diathermy. I tried the method for some years prior to 1939 but could detect no improvement in results as compared with operation by the scalpel. The method has certain dangers of its own. An old septic focus near the neutral electrode may be lighted up. In one of my cases this led to a fatal staphylococcal septicæmia. The badly nourished posterior flap may slough if an excess of current is inadvertently passed through its base.

It would appear that diathermized tissues possess a rather lowered resistance to infection, and in a small proportion of cases, after an apyrexial convalescence, about the tenth day the temperature rises, the skin-edges become red, and pus may form beneath the edges of the flaps, and even extend beneath them, as the result of infection by the skin organisms at the suture line. The process seems closely allied to fat necrosis.

The education of a surgeon in the technique of surgical diathermy is necessarily a gradual process, and familiarity with the method should be acquired by its use for smaller operations before it is adopted for such an extensive operation as that for carcinoma of the breast. Even given the necessary technical knowledge and familiarity with the method, and a really efficient machine, and admitting that diathermic excision lessens shock and hæmorrhage, maintains body temperature and probably divides nerves without stimulating them, I conclude, after a lengthened trial, that the scalpel operation is to be preferred.

Technique of the diathermy operation.—The first steps are the same as in the scalpel operation. A circle of skin four or five inches in diameter, with the primary growth at its centre, is marked out by a scalpel-scratch for removal. The flaps are marked out by two incisions, enclosing this circle, which extend from the epigastric angle to the insertion of the pectoralis major. The flaps are now undermined for about an inch all round, still with the scalpel in the mid-plane of the subcutaneous fat. The knife is now exchanged for the diathermy needle, and with it the elevation of the anterior skin-flap is completed so that the anterior half of the circle of the deeper subcutaneous fat, ten to twelve inches in diameter, and with the primary growth at its centre, is marked out for removal. The exposure of the posterior half of this same circle is deferred until the last moments of the operation, in order that the nutrition and warmth of the posterior flap may be safeguarded to the utmost.

All round the exposed semicircle of the subcutaneous fat the needle now is carried down to the level of the deep fascia, and, the flap being carefully retracted, the edge of the deep fascia is raised exactly as if the scalpel were being used. While the axillary dissection is being performed, the needle is laid aside and the dissection is done with gauze and dissecting forceps in the manner already described. The operation is then continued with the diathermy needle on exactly the same lines as if a knife were being used. The final step of the operation —the raising of the already undermined posterior flap—is done with the scalpel to avoid passing an undesirable amount of current through the base of the flap. Small vessels may be quickly sealed by contact of the diathermy needle with the forceps which hold them.

Plastic methods of operation on breast cancer.—The object of the surgeon in operating upon breast cancer is the complete removal of all those tissues which are likely to harbour extensions of the disease, and of those tissues only. This object is so difficult of attainment that all plastic methods which divert attention to the repair of the wound are radically unsound. *Tansini* practises a very free ablation of the growth with what appears to be an unnecessarily extensive removal of the surrounding skin, but without undermining the skin-flaps. He then fashions a flap in the scapular region. In the base of

this flap it is very probable that a segment of the growing edge of the disease will be left intact to cause recurrence.

Danger of inelastic methods of operation.—All methods which prescribe a fixed mode of attack, without regard to the situation of the growth in the breast, are essentially irrational. A carcinoma of the outer edge of the breast requires different treatment from one of the inner edge. The various faults apparent in different methods of operation mainly spring from a failure to base the operation upon a true and coherent conception of the mode of spread of the disease. The facts of dissemination are now well known, and there is no excuse for failure to take them into account.

Common faults in operations for breast cancer.—These may thus be summarized :—

(*a*) *The pursuit of minor aims which distract attention from the one great object of eradicating the growth.*

(*b*) Failure to base the operation rigidly upon the known facts of dissemination. In detail this is seen as :—

(*c*) Removal of an unnecessarily large area of skin.

(*d*) Removal of an inadequate area of deep fascia.

(*e*) Failure to centre the operation upon the primary growth, owing to the adoption of some rigid method which does not adapt itself to the varying situations of the growth in the breast.

(*f*) Failure to reach the apex of the axilla and to remove the subclavicular glands there situated.

Other faults, now rarely seen in British surgery, are :—

(*g*) Obviously inadequate operations, e.g. resection limited to the removal of the portion of breast containing the growth.

(*h*) Failure to remove the pectoral muscles.

Difficulties in the after-treatment.—*Shock* must be treated on general principles. Usually it is only seen after excessive bleeding, and especially when ether has been used as the anæsthetic. If the hæmostasis has been careful and complete, saline and stimulants can be given immediately after the operation without fear of exciting further bleeding. Severe and persistent shock was formerly common after the operation, owing to pain arising from the extreme tension of the sutures co-apting the flaps. Tension of the flaps must be avoided, if necessary, by skin-grafting. A third cause of shock is chill from neglect to cherish the flaps with hot towels during operation.

Collection of serum under the flaps is the commonest minor complication. It is often due to rough nursing or restlessness. It appears to result from the section of the lymph-vessels, especially in the axillary

region, which is inevitable during the operation. The flaps are separated from the chest-wall by a fluctuating water-cushion of serum. The difficulty must be met by daily insinuating a director at some point along the line of sutures and squeezing out the fluid. It is not advisable to re-introduce a drainage-tube, for fear of sepsis. If serum continues to collect after the incision has healed, a few days' hot fomentation will often cause the flaps to adhere to the chest-wall and will stop the lymphorrhœa, or the flaps may be fixed down by strips of strapping across the chest. Purgation with mist. alba may help. The arm should be kept in a sling until the lymphorrhœa has ceased.

Lymphorrhœa does not imply a bad ultimate prognosis. One of the most persistent cases I have met with remained free from recurrence seventeen years after the operation, when she died of an intercurrent disease.

Sloughing of the flaps is rare, except from unnecessary chill during operation, from undue tension, or from scoring of the flaps near their bases. The slough should be cut away with scissors, and the exposed area skin-grafted as soon as the flaps are adherent to the intercostals

Ulceration of the edges of the flaps is a common but not a serious trouble. Should it occur, the skin-edges should be sprayed twice daily with staphylococcus antivirus, the stitches should be retained longer than usual, and fomentations applied to clean up the wound.

Oxygen for the flaps.—In certain cases, especially if the patient is very thin or the growth excentric in the breast, anæmic areas may be seen at the end of the operation towards the edge of one of the flaps. In such cases it is my custom to place beneath the dressing the end of a small rubber catheter with its orifice in contact with the anæmic area. Through this catheter, during, say, the first week, a continuous current of oxygen is played upon the skin surface. The oxygen passes through a Wolff's bottle in which there is some water, and should be regulated to about 20 to 30 bubbles per minute.

Retraction of the flaps owing to yielding of the stitches, to their premature removal, to rough nursing or to restlessness, may delay convalescence very considerably. It is more likely if a heavy opposite breast is allowed to drag on the wound. This may be prevented by tilting the patient over to the side of the operation, or by applying on the outer side of the opposite breast a broad strip of strapping, which is carried over the wound and attached to a weight of 2 or 3 lb. hanging over the side of the bed. The sutures must not be removed too early, and if not causing irritation they should be left for nearly a fortnight.

Suppuration of the wound is a rare and serious complication. It is rarely fatal, but may lead to empyema. It must be treated vigorously by re-introducing large drainage-tubes at all dependent points and by frequent irrigations with 1-in-1,000 flavine. Carrel's method may be used with advantage.

Syncope.—In one case, unique in my experience, the patient died of

sudden heart-failure within a few hours of the completion of the operation.

Infections during convalescence.—In a general hospital ward, infection from other cases can never be entirely excluded. I have seen fatal influenza and broncho-pneumonia, and two serious cases of erysipelas, both beginning in the second week of a normal convalescence.

Limitation of freedom of movement of the arm.—Some surgeons, in order to maintain free abduction, keep the arm abducted nearly to a right angle throughout convalescence, and the practice is no doubt successful in its object. It is, however, unnecessary, and there is a serious objection to it in that it increases the tension on the skin-flaps. It must tend, therefore, to restrict their already precarious blood supply, and to favour sloughing and ulceration of their edges.

In my own practice the arm is kept fixed to the side in a sling until after the stitches are removed, to ensure relaxation of the flaps and absence of movement between the apposed skin-edges. When the union is firm at the end of a fortnight or three weeks, abduction is first allowed, then encouraged, and then insisted upon systematically. If necessary, abduction exercises, such as "climbing" the hand up the wall, are given. If the skin is tacked down to the ribs, massage, not of the skin, but of the skin upon the ribs, will soon loosen the adhesion. The hand is fixed upon the skin, which is then rocked in various directions upon the underlying ribs. If these simple precautions are taken there is no fear of limitation of movement.

As Kocher points out, leaving the lessor pectoral is more likely to lead to limitation of movement than its total removal. Any remaining portion of the muscle, if deprived of its nerve supply, will become contracted and fibrotic.

If the arm is kept to the side for several months owing to nervous [illegible] excision.

RECURRENCE

It would be possible to maintain that modern methods of operating for breast cancer have almost abolished recurrence, for, strictly speaking, recurrence means a return of the disease in the field of operation, and this after the modern operation is a rare event. It is, however, customary to include under the term recurrence any clinical manifestation of the disease which appears after the operation as the result of the development of inappreciable microscopic foci already present, at the time of the operation, in regions where the knife does not intrude.

Todd and Dawson* give an instructive table showing the sites of the first and second recurrences in 107 cases of breast cancer treated by operation only and not subjected to radiation.

* "Cancer," 1937, Edinburgh

Site	First Recurrence No. of Cases	Second Recurrence No. of Cases
Skin, in or near scar . . .	31	2
Deeper tissues of chest-wall and axilla	25	3
Supraclavicular lymph-nodes . .	26	5
Peritoneum	3	1
Liver	3	6
Lung	6	22
Other breast	2	4
Other axilla	0	3
Brain	1	1
Spine	8	10
Pelvis	0	5
Femur	2	6
Other bones	0	4
Total . . .	107	72

As the authors remark, the large number of skin recurrences could probably have been reduced almost to vanishing point by adequate post-operative radiation. Since axillary recurrence after efficient operation is a rarity, it is probable that most of the recurrences, 51 in number, under the second and third groups of the table were traceable to infected internal mammary glands. In my opinion this danger can be dealt with much more efficiently by radium tubes, implanted at the time, than by post-operative radiation.

I have arrived at the following classification of recurrences after operations for breast cancer :—

1. **Rapid recurrences,** within a year or so of operation. The site of these is variable and undefined. They are sometimes local, but are often internal. In these cases the disease is really inoperable when first seen, and, as a rule, further operation is not possible, except in cases where enlarged supraclavicular glands show themselves within a few months of the operation without any other manifestation of the disease

2. **Late recurrences** taking place generally more than two years after operation. A large majority of such cases fall into four subdivisions :—

(*a*) Intercostal recurrence
(*b*) Supraclavicular recurrence.
(*c*) Spinal and bone recurrences.
(*d*) Pleural recurrences

It is in dealing with late recurrences that the outlook has lately become much more hopeful As to supraclavicular recurrence, I am certain that in the past such cases have been looked upon from an unduly pessimistic standpoint A carefully planned operation for clearing the posterior triangle is the right treatment, and in a proportion of cases may give durable success

Intercostal and sternal recurrence.—In a regrettable proportion of cases, two to twelve years after the primary operation, a nodule or nodules, not at first adherent to the skin, appears at the inner end of one or more of the first, second, and third intercostal spaces. Later, these nodules become adherent to the skin. The sternum is also liable to attack by them, and a large sternal swelling may then arise. Nodules may later present at the inner ends of the lower spaces down as far as the sixth. (Fig. 305.)

Operative treatment and surface radiation are useless in dealing with this form of recurrence, but it is not quite so hopeless as it appears. Halsted records a success by treatment with the actual cautery. I had a case which remained well twenty years after the recurrence, which was treated by secondary X-rays. In this method X-radiation is preceded by local injections of bismuth. When irradiated, the bismuth particles become a source of soft secondary X-rays within the tissues.

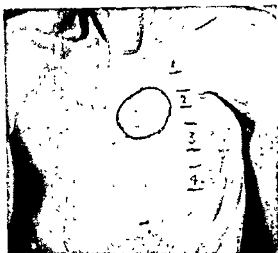


Fig. 305.—Operation for carcinoma of mammæ by Dr. Carson in 1912. Solitary sternal recurrence March, 1924, due to parasternal invasion of internal mammary chain before first operation.

The preceding methods have been superseded by the use of buried radium. The subject is not ripe for general statements but the following case illustrates the value of the method:—

Mrs. A. R. was operated upon for carcinoma of the left breast in 1918 by Miss Aldrich Blake. She was brought to me by the late Dr. Helen Chambers in 1925 with a prominent hemispherical recurrence on the left side of the upper part of the sternum in the second intercostal space closely resembling that seen in Figure 305. The growth was encircled by a ring of buried radium tubes and two tubes were placed in its soft centre. The strength of the tubes [illegible] Fig. 306. They were removed after [illegible] X-ray of the sternum taken in [illegible] clerosis at the site of the deposit. The patient remained well and active (1949) in her 82nd year. She died in 1952.

In such cases of parasternal recurrence I would now advise not only encirclement treatment of obvious nodules by 2 and 3 mg. tubes of RaEl buried for five days, but also prophylactic radiation by similar tubes of the whole length of both internal mammary lymphatic chains, and of the supraclavicular glands on the side of the growth.

Intramediastinal Radium for Invaded Internal Mammary Nodes

L. H., aged 76, had a left breast carcinoma treated by radium implantation on date unknown. First seen January, 1937, with recurrent lump, present 18 months, over inner end of second left intercostal space. It was adherent to skin and fascia. From

its position invasion of the left internal mammary chain was inferred On 26 1.37 a radical removal of the breast was carried out. The anterior mediastinum was then [illegible]

downwards as far as the fifth costal interspace. Upwards along the cord behind the first costal cartilage and reaching as high as the clavicle a second tube was inserted. Radium tubes (2 mg.) were also inserted at the inner ends of intercostal spaces 1 to 5 on the left side, and 1 to 4 on the right side, early infection of the right internal mammary chain being presumed. Tubes removed in five days The pathologist reported spheroidal-celled carcinoma with well-marked tubule formation. Smooth convalescence The patient remained well eight years later (November, 1945).

Supraclavicular recurrence.—The first sign of supraclavicular recurrence is the appearance of a large hard gland deep in the angle

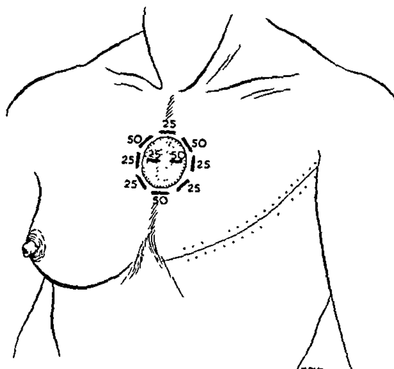


Fig. 306.—Radium dosage in a case of hemispherical carcinoma recurrence in sternum. (Case of Mrs. A.R.)

between the clavicle and the sterno-mastoid muscle overlying the subclavian artery. Later, other glands appear in the triangle below the posterior belly of the omo-hyoid muscle.

If the glands are still mobile, operation should be undertaken. Even if the gland at the lower and inner angle is fixed, it is sometimes worth attempting to enucleate it, and if a tube of radium is then left for twenty-four hours in the bed from which it came, and if at the same time all the glands in the posterior triangle are excised, a long period of freedom from recurrence may be secured It is, however, useless merely to excise the enlarged glands. The adjoining glands, though still normal in size, are microscopically infected. Accordingly it is necessary, as Butlin first advised, to excise all the glands in the posterior triangle, including the deep cervical glands lying within the carotid

sheath. At the very least, the gland excision should be carried as high as the spinal accessory nerve.

Mode of operation.—An incision is made along the posterior border of the sterno-mastoid from the mastoid process to the sterno-clavicular joint. Here it turns sharply and follows the clavicle as far as the edge of the trapezius. The triangular flap thus defined is raised outwards as far as the margin of the trapezius, and is wrapped in a hot towel. Included in the flap are the platysma and a layer of subcutaneous fat. A length of the external jugular vein is included, so that this vein is divided twice, once in the upper part of the skin incision, and again where it penetrates the deep fascia just above the clavicle. Andreassen* recommends as preferable an incision from the sterno-clavicular joint upwards and outwards to the edge of the trapezius, bisecting the angle between the clavicle and the edge of the sterno-mastoid.

The posterior border of the sterno-mastoid is now defined, and the spinal accessory nerve is exposed at its exit from the muscle, and cleared in its course across the triangle. Unless this is done, the nerve, which is here embedded in very dense tissue, will certainly be cut during the operation.

The sterno-mastoid is now retracted inwards, exposing the anterior belly of the omo-hyoid and the sheath of deep fascia covering the internal jugular vein. The fascia is carefully snicked so as to expose the vein; a director is then introduced through the opening in the fascia, first in an upward and then in a downward direction, and the layer of fascia is divided cleanly, along with the omo-hyoid muscle, from the mastoid to the clavicle. The clean performance of this step is the key to the whole operation.

The jugular glands are now swept outwards by gauze dissection. The deep fascia is divided on a director just above the clavicle, and the lower and inner angle of the triangle is opened up. Here a large gland, often adherent, is found behind the inner end of the clavicle. This part of the dissection is very important. When it is accomplished, the gland-bearing layer of fibro-fatty tissue can be swept outwards by gauze dissection, with occasional division of small arteries, as far as the outer edge of the trapezius. The fascia covering the brachial plexus is now exposed, but should not be opened. The sheet of tissues is turned back into position, the edge of the trapezius is defined, and with scissors the freed tissues are divided along the outer edge of the triangle. The omo-hyoid is cut again near its origin from the scapula, and here free bleeding is encountered.

A 3-mg tube of radium is then placed with its point deeply behind the inner end of the clavicle, another upwards along the main deep cervical chain, almost up to the base of the skull, one outside the lower exposed portion of the internal jugular vein, one behind and parallel with the clavicle, and one in the outer angle of the posterior triangle. The tubes are removed in five or six days. No tube should be placed in contact with the brachial plexus. The threads emerge in suitable positions

* *Journal Internationale de Chirurgie*, Jan., 1949.

its position invasion of the left internal mammary chain was inferred. On 26.1.37 a radical removal of the breast was carried out. The anterior mediastinum was then explored through the inner end of the second space by division of the intercostal muscles, and a cord of fibrous new growth was found running with the internal mammary vessels. Along this cord, and behind the costal cartilages a 3-mg. radium tube was inserted downwards as far as the fifth costal interspace. Upwards along the cord behind the first costal cartilage and reaching as high as the clavicle a second tube was inserted. Radium tubes (2 mg.) were also inserted at the inner ends of intercostal spaces 1 to 5 on the left side, and 1 to 4 on the right side, early infection of the right internal mammary chain being presumed. Tubes removed in five days. The pathologist reported spheroidal-celled carcinoma with well-marked tubule formation. Smooth convalescence. The patient remained well eight years later (November, 1945).

Supraclavicular recurrence.—The first sign of supraclavicular recurrence is the appearance of a large hard gland deep in the angle

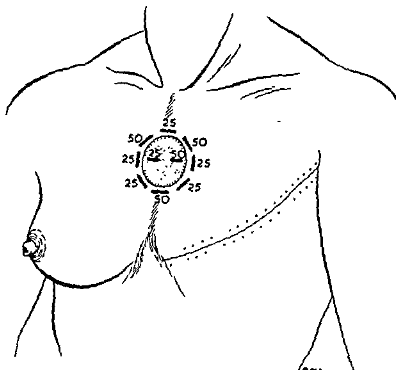


Fig. 306.—Radium dosage in a case of hemispherical carcinoma recurrence in sternum. (Case of Mrs. A.R.)

between the clavicle and the sterno-mastoid muscle overlying the subclavian artery. Later, other glands appear in the triangle below the posterior belly of the omo-hyoid muscle.

If the glands are still mobile, operation should be undertaken. Even if the gland at the lower and inner angle is fixed, it is sometimes worth attempting to enucleate it, and if a tube of radium is then left for twenty-four hours in the bed from which it came, and if at the same time all the glands in the posterior triangle are excised, a long period of freedom from recurrence may be secured. It is, however, useless merely to excise the enlarged glands. The adjoining glands, though still normal in size, are microscopically infected. Accordingly it is necessary, as Butlin first advised, to excise all the glands in the posterior triangle, including the deep cervical glands lying within the carotid

sheath. At the very least, the gland excision should be carried as high as the spinal accessory nerve.

Mode of operation.—An incision is made along the posterior border of the sterno-mastoid from the mastoid process to the sterno-clavicular joint. Here it turns sharply and follows the clavicle as far as the edge of the trapezius. The triangular flap thus defined is raised outwards as far as the margin of the trapezius, and is wrapped in a hot towel. Included in the flap are the platysma and a layer of subcutaneous fat. A length of the external jugular vein is included, so that this vein is divided twice, once in the upper part of the skin incision, and again where it penetrates the deep fascia just above the clavicle. Andreassen* recommends as preferable an incision from the sterno-clavicular joint upwards and outwards to the edge of the trapezius, bisecting the angle between the clavicle and the edge of the sterno-mastoid.

The posterior border of the sterno-mastoid is now defined, and the spinal accessory nerve is exposed at its exit from the muscle, and cleared in its course across the triangle. Unless this is done, the nerve, which is here embedded in very dense tissue, will certainly be cut during the operation.

The sterno-mastoid is now retracted inwards, exposing the anterior belly of the omo-hyoid and the sheath of deep fascia covering the internal jugular vein. The fascia is carefully snicked so as to expose the vein; a director is then introduced through the opening in the fascia, first in an upward and then in a downward direction, and the layer of fascia is divided cleanly, along with the omo-hyoid muscle, from the mastoid to the clavicle. The clean performance of this step is the key to the whole operation.

The jugular glands are now swept outwards by gauze dissection. The deep fascia is divided on a director just above the clavicle, and the lower and inner angle of the triangle is opened up. Here a large gland, often adherent, is found behind the inner end of the clavicle. This part of the dissection is very important. When it is accomplished, the gland-bearing layer of fibro-fatty tissue can be swept outwards by gauze dissection, with occasional division of small arteries, as far as the outer edge of the trapezius. The fascia covering the brachial plexus is now exposed, but should not be opened. The sheet of tissues is turned back into position, the edge of the trapezius is defined, and with scissors the freed tissues are divided along the outer edge of the triangle. The omo-hyoid is cut again near its origin from the scapula, and here free bleeding is encountered.

A 3-mg. tube of radium is then placed with its point deeply behind the inner end of the clavicle, another upwards along the main deep cervical chain, almost up to the base of the skull, one outside the lower exposed portion of the internal jugular vein, one behind and parallel with the clavicle, and one in the outer angle of the posterior triangle. The tubes are removed in five or six days. No tube should be placed in contact with the brachial plexus. The threads emerge in suitable positions

* *Journal Internationale de Chirurgie*, Jan., 1949.

along the line of incision. For purposes of drainage, and for the withdrawal of the radium tubes, a stab-wound is made through the base of the flap near the edge of the trapezius. The wound is then sutured with interrupted horsehair, or by clips.

Dangers of the operation.—The operation just described is a delicate dissection requiring precise anatomical knowledge, and its dangers are obvious. A risk special to the left side is that of wounding the thoracic duct, a misfortune which has once happened to me. If the accident is detected, the injured duct should be ligatured As a rule, the collection of serum under the flap, and copious soakage through the dressings, are the first indication. Persistent firm bandaging, preferably by rubber bandages, continued for several weeks, will ultimately staunch the flow in most cases, and a fatal result appears to be rare.

If cancer-cells have already passed outside the glands by infiltration of the capsule, an event usually indicated by fixation, operation is likely to be followed rapidly by diffuse cancerous induration beneath the operation flap, from implantation of cancer-cells upon the raw surface of the wound. The condition of the patient is then much worse than before the operation. This danger can be minimized by refusing to operate when the glands are fixed, by burying a whole group of radium tubes in the wound at the time of the operation, and by post-operative X-radiation. The two latter precautions may with advantage be used in all operations for cancerous glands.

Not infrequently a moderate lymphorrhœa follows the operation and produces, after healing of the wound, a hard lymphatic œdema of the tissues of the operation area which may be mistaken for cancerous infiltration. Time brings about softening of the indurated tissue.

Other forms of recurrence.—Axillary recurrence and recurrence in the subclavicular glands are nearly always preventable. Should they occur, they should be treated by buried radium followed and supplemented by X-radiation.

Castration in the treatment of breast cancer.—Adair *et al*,* discussing this subject, which in this country is associated with the names of Sir George Beatson and Sir Hugh Lett, estimate that it gives improvement in only 13 to 15 per cent. of cases, whether done by X-radiation or by operation, and that the improvement is only temporary. In male patients, however, Adair thinks that " the patients obtain the same striking improvement in general health as is shown in cases of carcinoma of the prostate which received castration."

Testosterone propionate in breast cancer.—Adair† has tried large doses (e g up to 4,000 mg. in three months and 1,000 mg. within five days). Of 11 patients, three with osseous metastases, and one with soft-part metastases, showed " remarkable improvement " evidenced by disappearance of pain and by recalcification of bone Initial hypercalcæmia is a contra-indication In such cases toxic

* Frank E Adair *et al*, *Journ Amer Med Assn*, May 19, 1945
† Frank E Adair and J B Herrmann, *Annals of Surgery*, June, 1946

symptoms may develop. The treatment, given by injection or implantation, should be controlled by serum calcium estimations. Recalcification is accompanied by a rise in the alkaline phosphatase content. The benefits of the treatment are unpredictable in amount and duration, and are not permanent, but the hope of relief of pain in inoperable cases warrants its trial. Masculinization effects must be expected.

Carcinoma of the Male Breast

About 1 per cent. of cases of carcinoma of the breast occur in males. In the male the disease develops under unfavourable conditions as regards the vascular supply of the part, and the primary growth often remains small and apparently insignificant. Frequently no notice is taken of the growth until it ulcerates; that is to say, male carcinoma reaches the surgeon at a later stage than carcinoma in the female.

It must not be forgotten that in the male the process of permeation has but a very short distance to travel before it reaches the fascial lymphatic plexus subjacent to the breast. There is no warrant for the assumption that, when it reaches this plexus, permeation spreads in it more slowly than in the female. However small the primary growth, it is necessary, especially if there be ulceration, to reckon with the probability of widespread permeation of the fascial plexus.

Many surgeons, when operating for male carcinoma, ignore these considerations, and perform an operation they would admit to be hopelessly inadequate in a female.

Unless the method of Keynes is adopted, i.e. limited excision with extensive use of implanted radium tubes in the surrounding tissues, the operation in the male should be conducted on the same lines as in the female The removal of a 4-in. circle of skin and a 10-*in*. circle of deep fascia is demanded, and the pectorals must be ablated. Owing to the absence of fat, the raising of the skin-flap is a more difficult and delicate operation than in the female, and it is very important not to allow the thin flaps to become chilled. It is usually impossible, owing to the absence of "slack", to bring the flaps together, and skin-grafting can rarely be dispensed with.

Sarcoma of the Breast

Sarcoma of the breast should be treated on the same lines as carcinoma, and removal of the axillary glands should not be omitted. Frequently, owing to extensive skin-adhesion, wide removal of the skin is necessary, and skin-grafting has to be performed.

Ultimate Results of the Operation for Breast Cancer

Personal results.—It has been my practice not to refuse operation for breast cancer in any case where a favourable result appeared at all possible,

and, while my statistical results have doubtless suffered in consequence, some individual patients who on ordinary standards were inoperable have reaped great benefit. I may instance a schoolmist[illegible] the first operati[illegible] axilla. [illegible] years. ultima[illegible] deposits. Another patient, a washerwoman, showed a large secondary deposit in the opposite breast, with hard glands in the opposite axilla. She followed her laborious work for two years subsequently, and then developed signs of thoracic invasion from which she died. Other cases had already reached the stage of ulceration when operated upon.

Including all the advanced cases in which operation was done more as a palliative than with the hope of cure, 47 per cent. of those of my patients who could be traced have remained free from recurrence for a period of three years or upwards. Since I began to use radium at the time of the operation this figure has gone up to 56 per cent.

When it is remembered how few really early cases of breast cancer a surgeon sees in this country, the results are not entirely unsatisfactory. I estimate that of the cases of breast cancer which I see, 90 per cent. already have enlarged axillary glands. Local recurrence in or beneath the operation-flaps—formerly so common—is now rare, and the bulk of the recurrences must be ascribed to carcinoma-cells which already, at the time of the first operation, had passed into regions beyond the scope of the operation.

Results of other surgeons.—Sir Watson Cheyne's results, published in 1904, showed 50 to 55 per cent. of operable cases free from recurrence at the end of three years. Halsted, in 1907, published a series of 232 operable cases in which 38·3 per cent. had remained well at the end of three years; 18 cases which could not be traced were considered as dead of their disease. Since, in my experience, such patients may turn up in good health years afterwards, Halsted's statistics are probably more favourable than they appear.

We are indebted to this surgeon for a careful comparative study of the chances of cases with and without axillary involvement. Of the cases where the axilla had not been invaded, 80 per cent. remained free from recurrence for three years. The corresponding figure for the cases with axillary involvement was 22 4 per cent. only. These figures emphasize the importance of educating the public to seek earlier advice. Still more loudly do they call for an effective means of sterilizing invaded parasternal glands, proved microscopically by R S. Handley and A. C. Thackray to be present in 33 of 100 consecutive operable cases.

Judd and Sistrunk (Mayo Clinic) reported that of 510 traced cases operated on in 1902–12, 44·7 per cent. remained well for three years, and 29·8 per cent. for five years.

Deaver, McFarland and Herman report 34 per cent. well after three years in a series of 506 cases, of which they were able to trace 150, while 26 per cent. were well after five years.

Carter Braine and Grant Massie (*Guy's Hosp. Rep.* 1926, lxxvi, 484) give the following statistics :—

PERCENTAGES OF THREE- AND FIVE-YEAR SURVIVALS

Author	Date of Paper	No. of Cases	Survival After 3 Yrs.	Survival After 5 Yrs.
			per cent.	per cent.
Handley . . .	1922	—	47·0	—
Peck and White .	1922	118	—	39·1
Primrose . . .	1923	49	—	44·4
Leeds Series . .	1926	357	48·7	35·7
Guy's Hospital Series	1926	338	54·1	28·4

COMPARATIVE PROGNOSIS WITH AND WITHOUT AXILLARY INVASION

Author	Cases	Glands Invaded Alive at 3 Years	Glands Invaded Alive at 5 Years	Glands Free Alive at 3 Years	Glands Free Alive at 5 Years
		per cent.	per cent.	per cent.	per cent.
Dahl (1925) . .	83	20 34	15·79	70·83	66·67
Sistrunk (1921) .	218	—	18·90	—	63·00
Guy's Hospital Series (1926) . . .	120	45·80	18·80	86·50	46 00

Gordon-Taylor in 1938 recorded a personal experience of 603 cases at the Middlesex Hospital. Only 7 cases were untraced. Post-operative radiotherapy was not used in Group I and Group II cases. Radiation alone, without operation, was employed in 39 instances, 3 in Group I, 8 in Group II, and 28 in Group III. In the last group, 3 patients survive; 2 now dead lived 8 and 5½ years. Among 29 patients, judged unfit for radical operation who were treated by local removal of the breast and subsequent radiation, 2 only survived in 1938 but the series included survivals of 10, 8½, 6 and 5 years. The results of Gordon-Taylor's radical operations from 1908 to 1928—603 in number, excluding the 7 untraced ones—are shown in the following table, and the series includes a large number of ten-year survivals.

CASES TREATED BY RADICAL OPERATION, 1908–1928, FOLLOWED UP AFTER 10 YEARS (GORDON-TAYLOR): 363.

	Total Cases	Surviving 10 years Alive	Surviving 10 years per cent.
Group I cases	113	95	84
" II "	204	60	29·4
" III "	46	3	6·5

CASES TREATED BY RADICAL OPERATION, 1908–1933, AND FOLLOWED UP AFTER FIVE YEARS: 497.

		Surviving 5 years	
	Total Cases	Alive	per cent.
Group I cases	163	140	85
„ II „	283	113	39·9
„ III „	51	5	9 8

CASES TREATED BY RADICAL OPERATION, 1908–1935, AND FOLLOWED UP AFTER THREE YEARS: 551.

		Surviving 3 years	
	Total Cases	Alive	per cent.
Group I cases	172	147	85·4
„ II „	320	150	46·8
„ III „	59	6	10·1

Of 156 patients who survived radical mastectomy 10 years or more, 8 survived 25 years, 6 between 20 and 25 years, 33 between 15 and 20 years, and 111 attained a ten-year survival.*

The Marie Curie Hospital reports on 418 cases of breast cancer, treated since 1925 either by radiation alone or by radiation combined with surgery, and traced more than five years. Thirty per cent. survived five years. Of 186 cases traced ten years after treatment, 18·5 per cent. were still living. About one case in five was considered unsuitable for treatment. No separate statistics are given for cases treated by radiation only.†

The Westminster Hospital reports 33 per cent. of five-year survivals in 57 cases following all methods of treatment. The survivals in Stages 1, 2 and 3, were respectively 50, 38 and 20 per cent B. M. Truscott‡ has analysed the result in 836 cases of breast cancer treated at the Middlesex Hospital during the years 1926–35, and 265 cases treated in 1936–40 Seventy-two per cent. of all traced cases died from the disease within ten years. The liability to recurrence diminished with each five-year period, but was still high ten to fifteen years after treatment.

0–5 years	394 recurrences	in 734 cases	53·5	per cent.
5–10 „	50 „	„ 199 „	25	„ „
10–15 „	11 „	„ 89 „	12·5	„ „

In the earlier years surgery alone gave better results than surgery with radiation. After 1936, following a change in X-ray methods, results in the latter class improved, and in Stage 1 cases were slightly better than those given by surgery alone.

Truscott's careful paper does not separate the numerous advanced cases in which palliative radical operations were done, nor did his material allow

* Sir G. Gordon Taylor, *Brit Med Journ*, 1938, ii, 1069.
† Report for 1947 of the Brit Emp Cancer Campaign
‡ B McN Truscott, *Brit Journ. of Cancer*, 1947, i, 129

him to deal with the principal cause of recurrence, namely pre-operative infection of the internal mammary lymphatic chain (see p. 725).

H. Rosenquist* has recently reported on the experience of the Karolinska Sjukhuset at Stockholm, 1940–48, comprising 1,014 cases. Since 1931 the frequency of breast cancer in Sweden has increased by 70 per cent. while the population has increased only 12 per cent. The usual treatment has been pre-operative X-ray therapy in a dose of 1,000 to 1,500 r. followed in four weeks by a Halsted-Handley operation. The post-operative X-ray treatment consists of two or three series of 1,000 r. during one week. The five-year survival figures are for Stage I 79·1 per cent., for Stage II 46·4 per cent., for Stage III (palliative operations) 11·1 per cent.

Rosenquist rejects McWhirter's method as giving results not so good as the present Stockholm methods, defends pre-operative radiation while admitting it has minor disadvantages, and stresses the necessity of removing the lesser pectoral muscle. Only eleven axillary recurrences were noted in 1,014 cases, and in all of these the operator had left the lesser pectoral.

It is unnecessary to pursue this subject further, for, owing to differences in the material of different operators, to variations in their selection of cases and their method of operation, and to the progress of post-operative radiation treatment, no close comparison between the different sets of figures can be established. It is, however, interesting to note, as measuring the improvement in results to date, that v. Winiwarter's statistics for 1867–75 showed only 4·7 per cent. of cases well for three years, and that, prior to Halsted's 1889–94 figures showing 45 per cent. of 76 cases well for three years, the best series of cases could only claim 28·5 per cent. of three-year successes. In 1889, in the collected German statistics, it was found that only 17·2 per cent. of patients with breast cancer remained well for three years after the operation. Gross, writing in 1888, reported that in the United States only 11·88 per cent. of cases remained well for three years or over.

Immediate mortality.—Billroth, in 1867–75, experienced a mortality-rate of 23·1 per cent. in his operations for breast cancer. With the advent of Listerism the rate rapidly fell, and between 1889 and 1894 Halsted's mortality in 76 cases was nil. In 1907 Halsted recorded 232 cases with a mortality of 2·5 per cent. Deaver (1898-1913) records 506 cases with a mortality of 0·98 per cent.; 2 of his cases died of endocarditis, and 1 each of uræmia, pneumonia, and sepsis. His estimate of 1 per cent. as the present death-rate of the operation may be accepted as a fair one. Judd, in 1912, recorded a series of 609 cases with 8 deaths (pulmonary embolism, sepsis, diabetic coma).

Cade (1948) reports the average mortality of 11,014 radical operations by a group of 22 British surgeons as 1·65 per cent. Victor Riddell (1948) records 170 radical operations without a death, a remarkable result in a period of war-strain and malnutrition.

NON-MALIGNANT MAMMARY AFFECTIONS

Simple Removal of the Breast: Mastectomy

The operation for removal of the breast is usually referred to as amputation of the breast The use of the term amputation is, however, an encouragement to rough and inartistic surgery, and should be abandoned in connection with the breast. The word mastectomy is more suitable.

* Rosenquist Translation of 25th meeting of the Northern Surgical Association in Copenhagen, 1951.

Indications.—Removal of the breast may be necessary for duc papilloma, for chronic mastitis occurring towards middle age, fo tuberculosis or actinomycosis, for cases where, after an abscess, th remains of the breast are riddled with discharging sinuses, and fo severe degrees of simple hypertrophy. It may also be required fo large innocent tumours to which the breast itself forms a mere appenc age. In tropical countries, elephantiasis of the breast may possibly ca for it. (See also section on Plastic Surgery, Vol. II.)

Incision.—An elliptical incision is used, removing a comparativel small ellipse of skin. *But if too small an ellipse is taken, the dissectio is more extensive and troublesome, and the ultimate result less sightl*

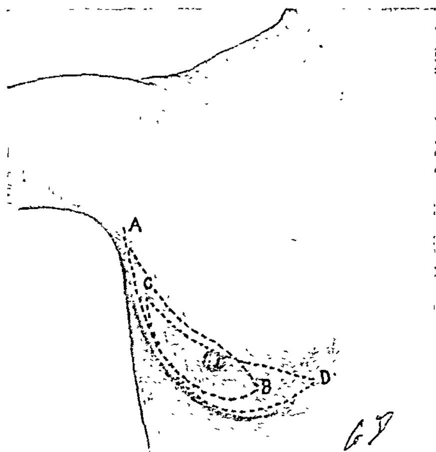


Fig. 307.—Simple mastectomy, showing alternative skin incisions, each removing narrow ellipse of skin, wider in the case of a voluminous breast. The upper limb of th ellipse, in any case, passes just above the areola.

C D is, on the whole, the best incision A B may be used where an inconspicuous scar is especially desired

owing to bagging of the redundant skin. The stouter the patient anc the larger the breast, the wider should the ellipse be made. Som operators have preserved the nipple, operating entirely below its leve and cutting across the ducts where they enter it. This procedure owing to inevitable fibrous contraction, is of no cosmetic value, and i

certainly introduces a risk of wound-sepsis from bacteria contained in the ampullæ of the ducts. This complication occurred in a case in which I tried the method.

Cosmetic considerations are not out of place in the operation, however. The lower the incision is placed, the less will it interfere with evening decolletage, and the less obvious will it be to the patient. Its upper limb should therefore pass only just above the nipple, while its lower limb passes below the nipple at a distance of 2 to 4 in. Such an incision includes the skin which is thinnest, most closely adherent to the breast, and most difficult to dissect up.

In ordinary cases the nipple may be taken as the midpoint of the long axis of the ellipse. If, however, an inconspicuous scar be especially desired, the incision may be carried only just internal to the nipple, and in compensation extended a little way into the vault of the axilla. This incision, it must be recognized, makes the dissection more troublesome in the region of the lower and inner quadrant, and is likely to leave a little redundant skin-fold in this situation. (Fig. 307.)

When the skin has been cut through vertically to its surface all round the ellipse, the knife, held at an angle of 135° to the surface, and entering just at the deep aspect of the dermis, is once more carried round the line of incision, dividing the fibrous septa that pass into the subcutaneous fat from the deep aspect of the skin. This allows the skin to retract, and facilitates the subsequent elevation of the skin-flaps.

Elevation of the skin-flaps.—The next step is the elevation of the skin-flaps. Here it must be remembered that breast tissue lies very closely underneath the skin. The flaps must therefore be cut as thin as is consistent with the maintenance of their nutrition. In thin subjects $\frac{1}{16}$ in. of subcutaneous fat should be left attached to the skin, in stout subjects as much as $\frac{1}{4}$ in. may be allowed. Scoring the flap must be avoided, especially near its base.

Many operators, perhaps the majority, only elevate the flaps as far as the visible margin of the breast, but they must be dissected back as far as the real limits of the breast. It is important to remove not only the prominent part of the breast but also its thin outlying edge. Stiles has shown that the breast is a much [illegible] an it appears to be. Breas[illegible] the nipple, from the lower border of the second rib to the sixth costal cartilage at the angle where it begins to sweep upwards towards the sternum. The horizontal diameter extends from a little within the edge of the sternum opposite the fourth rib to the fifth rib opposite the mid-axillary line. One oblique diameter extends from the upper border of the third costal cartilage a little outside the sternum, downwards and outwards to the seventh rib a little in front of the mid-axillary line; the other oblique diameter passes from the third rib a little beyond the anterior axillary fold downwards and inwards to the sixth costal cartilage midway between its angle and its sternal end.

It will be found that very many operations for amputation of the

breast fail to take account of these facts. Not infrequently, granular areas of mammary tissue are left at the periphery of the field of operation. *The removal of the breast is a larger operation than is usually thought*, and it demands careful dissection and a knowledge of anatomy, Since it is often performed to avert cancerous change, it is a serious fault to leave peripheral lobules. I have seen carcinoma develop in a residual part of the breast after mastectomy for a non-malignant condition.

Method of raising the flaps.—In thin breasts the flaps are best raised by ordinary careful dissection, care being taken to avoid scoring them. In the submammary fold especial care needs to be taken not to buttonhole the flaps In stout subjects, the manœuvre of subcutaneous transfixion, already described (p. 719), *shortens the operation considerably*, and should certainly be used. An artery of a size requiring immediate forcipressure is constantly found high up in the upper flap The flaps must be kept warm by relays of hot towels, or their edges may later necrose.

When the flaps have been dissected up all round as far as the periphery of the breast, the upper flap is drawn up by two retractors, held a little distance apart, and moved to suit the operator's convenience as he circumscribes the upper and inner hemisphere of the breast by an incision down to the muscle through the deep fascia. The breast is now quickly stripped from the pectoral muscle by long sweeps of the knife *parallel with the fibres of the muscle*. Several *perforating* branches of the internal mammary require ligature. In order not to leave any of the deep lobules which lie close to the muscle, it is necessary to clean the muscle, taking the pectoral fascia with the breast. When the serratus magnus is reached, gauze-stripping may be usefully substituted for dissection by the knife. Finally, the fascia along the base of the outer flap is cut upwards with the knife, and the breast remains attached by its axillary connections only. As these are divided, the vessels they contain, especially the long thoracic artery, are secured. A most careful search for bleeding-points over the whole field now follows. One or two branches of the intercostal arteries appearing through the serratus magnus usually need tying.

Drainage.—A drainage tube should emerge through a puncture in the base of the posterior skin-flap. It should be removed after 24 to 48 hours

Suture.—A continuous suture should not be used since it tends to shorten and pucker the line of the wound and to make it thicker and more evident. Interrupted double horsehair sutures are the best, as widely spaced as is consistent with accurate coaptation of the skin-edges. Michel clips may be used, but should be interspersed with a few sutures

Mastectomy with preservation of the nip [illegible] method practised by Stiles for this operation is an extensi [illegible] Gaillard Thomas

method of plastic resection. He recommends a semilunar incision along the submammary groove for an extent corresponding to the lower and outer hemisphere of the breast. The incision reaches above as far as the anterior fold of the axilla. In large and pendulous breasts it is advisable to remove a crescentic area of skin.

A semilunar skin-flap, with its convexity formed by the skin incision, is now raised from the lower and outer hemisphere of the breast. The nipple is raised up with the flap by division of the ducts of the breast as they approach their termination. The margin of the outer hemisphere is defined by dissection, and this hemisphere is raised from the subjacent muscles The isolated outer hemisphere is pulled strongly towards the operator, who then proceeds to undermine the skin covering the inner hemisphere. The assistant meantime retracts the skin-flap forcibly upwards. Reaching the inner margin of the breast, the operator is now able to raise the inner hemisphere from its deep connections, and the breast comes away. The assistant then everts the flap, and a careful search is made for bleeding-points. The perforating branches of the internal mammary must be ligatured. The flap is sutured back in position. Drainage is advisable.

Personally, I do not care for this operation. Its cosmetic results are not as good as might be expected, for the nipple, deprived of its support, hangs down as a flat tag, or may swell from lymphatic œdema. The redundant skin, too, is apt to fall into unsightly wrinkles. It is more difficult to secure hæmostasis in the recesses of the wound, and the divided main ducts communicating with the interior of the wound may give rise to sepsis. Possibly this last risk may be overcome by touching their ends with pure phenol or dusting the area with one of the sulpha group powders. On the whole, I consider that the ordinary operation with removal of the nipple is preferable even from the cosmetic point of view.

Complications of mastectomy.—The complications are those arising from hæmorrhage or sepsis, which, of course, should hardly ever be encountered.

Oozing may follow closure, especially in hot weather and in patients of active and irritable temperament. For this reason the operation should not be performed during menstruation. Two or three days' rest in bed is advisable before operation on an active and tired woman. Serious reactionary oozing is more frequent than after the longer operation for malignant disease, no doubt because less blood is lost during the operation itself, so that the circulation recovers before the small vessels are firmly sealed. Careful hæmostasis and an ice-bag over the dressing in hot weather may prevent it. Should it take place, and should the flaps be raised by palpable bloodclots and be deeply ecchymosed at the time of the first dressing, there is only one thing to be done. An anæsthetic must be given, the wound opened up, the clots washed away with a forcible stream of saline, and the wound resutured after bleeding-points (often at this time absent) have been

sought. The wound will now heal almost as well and as rapidly as if no bleeding had occurred. If nothing is done and the clot is left to organize, there will be ugly and possibly painful fibrosis and contraction, and the scar will be thick and unsightly. The clot may also become infected and suppurate.

Sloughing of the skin-edges may be due to scoring of the flaps, to cutting them too thin, or to allowing them to be chilled during the operation. The flaps are necessarily thin, of low vitality, and likely to be attacked by bacteria from their cutaneous ducts. An antiseptic dusting-powder applied after the operation may prevent this. Should slight sloughing or ulceration of the edges occur—and this is the worst that need be feared—they should be appropriately treated and the stitches should be left in longer to prevent retraction of the flaps. Any sloughs should be clipped away with scissors—not as a rule a painful procedure—and hot fomentations applied for a few days.

The patient, after mastectomy, may be allowed to get up as soon as she feels inclined; this is generally about the fifth day. Stitches may usually be removed in from five to seven days, and the wound then sealed with collodion. The earlier the stitches are removed, the less conspicuous will be the scar.

Partial Removal of the Breast

Resection of the breast is sometimes practised for any non-malignant condition involving a portion only of the gland—except in the case of

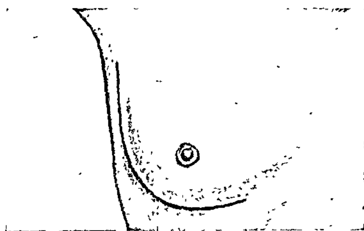


Fig. 308.—Gaillard Thomas's operation for removal of simple tumour of breast. First stage.

The skin incision follows the submammary sulcus

abscess or an easily enucleable simple tumour A radial incision, over the portion to be removed, may be employed, and through such a simple incision it is possible to remove a large portion of the breast.

In performing the resection, care must be taken not to interfere with the duct system of any portion of the breast which is not removed. If this rule is violated, obstruction cysts or mastitic indurations may

appear in the residual portion. The part of the breast removed should be included between two deliberately-made radial incisions through the breast substance, and these incisions should meet near the nipple, so that a clean wedge of the breast substance is removed. Hæmostasis should be very carefully attended to, and it is best to provide drainage for twenty-four hours. If the wedge removed is not too extensive, the cavity left may be obliterated by the lateral approximation of its walls with buried sutures of catgut passed through the breast substance.

As an operation, resection of the breast is less satisfactory in practice than in theory. The condition for which it was performed may later appear in the remaining portion of the breast. The operation itself may leave a local induration or an area of skin adhesion which may be

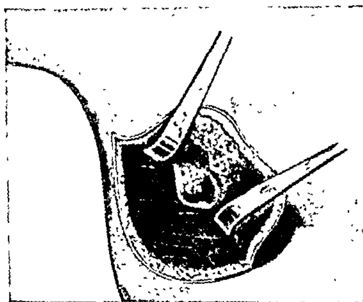


Fig. 309.—Gaillard Thomas's method. Second stage.
Exposure of the tumour from behind. Its capsule is now to be incised, and the tumour enucleated.

a cause of continuing anxiety. Therefore, in women approaching middle age, mastectomy is, in most cases, preferable to resection.

Resection of the breast through a submammary incision.—In order to avoid a scar upon the surface of the breast itself, Gaillard Thomas of New York, in 1882, suggested an incision round the lower hemisphere, or the lower and outer quadrant, following the submammary sulcus. When the upper edge of the incision is drawn up, the breast is easily, with little dissection, turned over so that most of its deep surface is exposed. (Figs. 308, 309, 310.) Simple tumours may then be enucleated by cutting down upon them through the deep aspect of the breast, or a portion of the breast harbouring the tumour may be resected. After this has been done and bleeding stopped, the breast is replaced in position and the incision sutured. It is usually best to drain.

The method of Gaillard Thomas is the method of choice for resection of a portion of the breast in young women, if the avoidance of a visible scar is desired, and if malignancy can be excluded with certainty. If a carcinoma is unexpectedly found, the operator will rue his choice of method, for it is impossible after such a dislocation of the breast to do a satisfactory radical operation.

Healing after the Thomas operation is usually rapid, and the cosmetic result good. This method is unsuitable for operations on the upper and inner part of the breast.

Mammary Suppuration

Acute mastitis and its sequel, abscess formation, almost invariably occur during lactation and are usually caused by staphylococci. Abscesses are most frequently found (1) just beneath the areola when the causative organisms enter through a crack in the nipple, or (2) in the substance of the breast, intra-mammary abscess, when infection

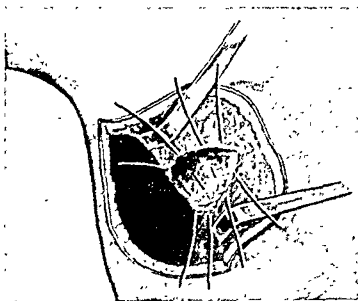


Fig. 310.—Gaillard Thomas's operation. Third stage.

Obliteration of the cavity in the breast left by the removal of the tumour The breast is then allowed to fall back into place, and the incision is sutured, with provision for drainage

is probably via the lumen of the ducts. Retro-mammary abscesses may be caused by the backward spread of an intra-mammary abscess, but large retro-mammary collections of pus suggest osteitis of the chest wall or an extension from intra-thoracic suppuration.

The incidence of mammary inflammation has been greatly reduced by the care now given to the nipples during pregnancy and lactation, and the advent of penicillin has much diminished the likelihood of abscesses following acute mastitis. The administration of 30,000 units of penicillin by injection every three hours for four or five days to all cases of acute lactational mastitis will usually cause resolution, and if the affected breast is kept empty with a breast pump it is often

unnecessary to interrupt lactation. Breast abscesses in which fluctuation is present require evacuation of the pus and penicillin administration.

Operative details.—In order to avoid injury to the ducts, incisions into abscesses must radiate from the nipple or be made round the circumference of the breast. The incision in the first instance should be of such a size as just to admit the finger which is introduced into the cavity to break down loculi and septs and open the recesses freely into the main cavity. A drainage tube, ¼ to ½ inch in diameter, is introduced. If the original incision proves not to be at the lowest point of the cavity, a counter incision is made at that point, a tube inserted and the first incision sutured. If the drainage tube is to be used for instillations of penicillin solution, the incision which carries it may be sutured round it.

The principal point in the after-treatment is the continuance of systemic penicillin. Instillations of penicillin into the abscess cavity, if they are to supplement systemic administration, should be done twice daily after the expression of pus, using a solution of 1,000 units of penicillin per c.c. When a breast abscess is large, lactation will have to be stopped by giving one of the synthetic œstrogens by mouth (e g. dienœstrol, 5 mg. t.d.s. for one day, 4 mg. t.d.s. for one day, 3 mg. t.d.s. for one day, and 2 mg. t d.s for one day). Small abscesses do not require the arrest of lactation, but the child should not be fed on the affected breast which should be emptied with the breast pump Drainage tubes can usually be removed from abscess cavities about the fifth day, but the exact time of removal must depend on clinical progress. For the first few days after a breast abscess has been incised, the arm should rest in a sling, with occasional short intervals for exercise of the shoulder and elbow joints. Activity of the pectoral muscles delays healing.

Florey and his colleagues have recently reported success in the treatment of breast abscesses which contain less than 10 c.c. of pus by aspiration of pus and replacement by 150,000 units of penicillin dissolved in a bulk of water slightly less than that of the pus aspirated. The process is repeated daily for four to seven days. Sinuses are liable to form round the needle track, especially if the needle is left indwelling in the abscess cavity, and the induration may take some weeks to subside, but lactation can be allowed to continue.

The results of what is often called the old-fashioned treatment of abscess of the breast are usually supposed to have been unsatisfactory If the cases were properly managed, that evil reputation was quite unjustified. We ought to realize that inflammation of the breast is a serious condition and that one of the most important factors in its management is rest in bed When suppuration is obvious or inevitable a free incision two inches or more in length into the substance of the breast and radiating from the nipple is necessary For this to be properly made some type of general anæsthesia is essential The incision should be left open and only lightly packed with vaselined gauze, the wound being allowed to close by granulation When healing is well under way the patient may be allowed out of bed, but the breast must be supported In the majority of cases the abscess heals readily The resulting deformity of the breast is inconspicuous and not destructive of subsequent function The cases that do badly are those that are not taken seriously and in which a totally inadequate incision is made Before the penicillin days, there were cases in which the suspected abscess did not mature, a sector of the breast remaining indurated and extremely tender while the patient continued to feel ill and to exhibit the general disturbance associated with inflammation. In these circumstances a free incision deep into the indurated area was nearly always followed by complete relief and reasonably quick healing. Three or four weeks will be required for recovery These experiences should be borne in mind at the present day, for though none would deny the benefit likely to result from the systemic use of penicillin it is important to recognize that aggressive surgery may be extremely helpful as an ancillary method. (Editor, G G T.)

Enucleation of Fibro-adenomata

The skin incision may be (*a*) a radial incision directly over each of the tumours, or (*b*) the Gaillard Thomas incision at the lower margin of the breast (p. 753). The tumour is enucleated through an incision on the deep aspect of the breast.

Usually the former or direct method is preferable, as being easier and simpler. The only advantage of the Thomas method is that it leaves no scar on the surface of the breast. It is a larger and sometimes not an easy operation.

Direct method.—The tumour is grasped firmly by the fingers of the left hand, and a vigorous cut, radiating from the nipple, is made over it. The cut must freely divide the capsule of the tumour, exposing its substance. This is the key to easy performance of the operation. The capsule is usually feebly adherent to the tumour, but firmly adherent to the surrounding breast substance. The common mistake is to attempt the difficult task of enucleating the tumour in its capsule from the surrounding mammary tissue before dividing the capsule.

When the capsule is divided, a blunt instrument is introduced within it and swept round. The finger sometimes proves the most effective enucleator.

The only common complication is the formation of a hæmatoma in the cavity. This is prevented by (*a*) careful hæmostasis, (*b*) obliteration of the cavity by one or more buried sutures approximating its sides, (*c*) drainage for twenty-four hours by a small tube, (*d*) firm bandaging, (*e*) fixation of the arm to the side.

Should a hæmatoma form, it will probably be best to open up the wound, remove the clot, obliterate the cavity, and resuture.

Large, soft, rapidly-growing adenomata are often best treated by removal of the whole breast.

It must not be forgotten that certain carcinomata of low virulence may acquire a fairly complete capsule and may be enucleable without very much difficulty. Accordingly, *all* tumours enucleated from the breast must be microscopically examined to exclude malignancy.

Surgery of Duct Papilloma and Precancer

In duct papilloma, as evidenced by persistent serous or sanious discharge from one or more of the nipple orifices, a simple mastectomy is usually the best treatment if the patient has reached the cancer age. This rule, however, is not without exceptions. If physical pride is an important factor, it may be recalled that even in fully developed carcinoma, treatment by buried radium tubes after the manner of Keynes is frequently successful. Surface papillomata are well known to be often amenable to radium; why not those within the ducts of the breast?

Localization of the papillomata.—It is important as a preliminary, if possible, to locate the papillomata. The number of discharging

orifices seen on the nipple is a guide to the number of lobes affected. Lenthal Cheatle has demonstrated, by the method of giant sections, that the disease affects the breast by lobes. The affected lobes are often outlined as vaguely indurated "mastitic" areas. More precise indications can often be obtained by local pressure with one finger upon successive areas of the circle of tissue immediately around the nipple, or further out at the margin of the areola. When the diseased lobes are pressed upon fluid is seen to emerge from the nipple. The actual papillomata themselves can rarely be felt.

Radium treatment.—Through multiple punctures in the skin-surface radium tubes, each of 2 or 3 mg. and distributed as uniformly as possible, are introduced behind or in the breast, in any case not immediately

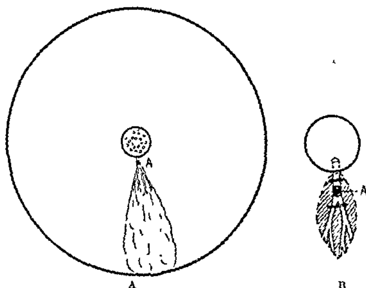


Fig. 311.—Excision of a palpable papilloma together with a length of the duct in which it lies.

(a) The breast, with the papilloma, A, and the indurated corresponding lobe. (b) The retracted radial skin incision, with exposure of the ducts before removal of a length of duct including the papilloma.

under the skin, for a period of five to seven days. If the papillomata cannot be located, the whole breast must be treated, and it should receive about the same dose as would be given for a carcinoma, though the axilla need not be treated. Fifty or sixty milligrams of radium will be needed. The amount varies with the volume of the breast, and the method is hardly applicable to a very voluminous mamma.

If the papillomata have been located, treatment may be confined to the affected lobe or lobes and a smaller amount of radium will suffice.

In my experience radium treatment will cure about two out of three cases of duct papilloma. X-ray treatment is rarely of any use.

Excision of the papillomata.—The most artistic method of treating papillomata is only possible when they can be felt. In rare cases a tiny shotty swelling can be palpated near the nipple, indicating a papilloma of some size in one of the large ducts. By a small incision 1–1½ in.

long radiating from the nipple over the swelling, the duct, usually dilated and sometimes dark from the blood within it, may be exposed





A B

Fig. 312A.—Duct papilloma becoming carcinoma.

P, papilloma, lying in a dilated duct which is surrounded by old adventitious fibrous tissue, the result of bacterial duct-infection A B, pedicles of two papillomata which have fused together. C C, dilated veins the rupture of which caused the hæmorrhage.

Fig. 312B —The earliest stage of duct carcinoma of the breast. High-power photograph of the pedicle B.

At A A are two groups of epithelial cells embedded in cicatricial fibrous tissue in the wall of the duct These foci represent the beginning of malignant infiltration.

in the dense tissue in which it lies. By careful dissection it is followed up until it begins to ramify in the breast. It is verified that the

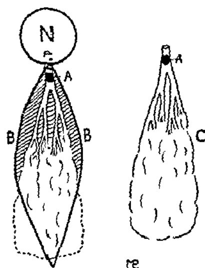


Fig. 313.—The operation of lobectomy for papilloma affecting one lobe only, but not accurately localizable.

N, nipple B B, retracted radial skin incision A, papilloma C, lobe of the breast after removal

shotty swelling previously felt lies within the duct Artery forceps are applied to the duct on either side of the swelling, which is then excised with the portion of duct in which it lies. (Fig 311) Owing

to the density of the fibrous tissue around the ducts, the operation is a troublesome and finicking one, requiring good eyesight and miniature instruments.

Papillomata of this kind may be entirely innocent, or upon section the substance of the papilloma may be found infiltrated by its own epithelium, and the growth, though it has not yet infiltrated the physiological tissues of the patient who produced it, is nevertheless a potential carcinoma. For such a papilloma the name "precancer" seems appropriate. In still other cases, incipient infiltration of the patient's tissues may be found beneath the base of attachment of the papilloma, which is clearly then an early carcinoma. (Fig. 312.)

The operation for a papilloma which cannot be accurately localized is illustrated in Fig 313.



(Editor G Grey Turner)

CHAPTER XIV

OPERATIONS FOR ABDOMINAL INJURIES*

By G. GREY TURNER

CONTUSIONS

CONTUSIONS of the abdominal wall owe their importance to the possibility of some underlying injury to the viscera. Any intra-abdominal organ may be ruptured without the association of superficial injury, and, as all abdominal injuries give rise to more or less shock, it may be very difficult to make a diagnosis. Rupture of a hollow viscus must be recognized early if treatment is to be successful, and the surgeon must not wait for signs of developing peritonitis to help in the diagnosis. When there is a penetrating wound the abdomen must be opened and explored at the earliest possible moment.

Rupture of a solid viscus often gives signs of internal hæmorrhage, and the organ may be identified by a corresponding injury to the ribs in the case of the liver and spleen, or other localizing signs. Sometimes injury of the intestine is associated with internal hæmorrhage when the mesentery is torn But if the diagnosis of rupture of a hollow viscus is to be made in time for successful surgical intervention, it can be arrived at only by continual observation at the bedside. In all these cases there is shock, and for perhaps two hours it may be impossible to decide whether the injury is severe or not. But, with appropriate treatment, shock tends to pass off if uncomplicated, so that if, after two hours, the condition of the patient is not improving, some deep-lying injury may well be suspected. Evidence is obtained from the facial appearance, the respiration, abdominal examination, the pulse-rate and blood examination. The most important physical signs are rigidity, local tenderness, fluid in the flanks, and, above all, free gas in the peritoneal cavity as shown by the replacement of liver dullness by a tympanitic note X-ray examination helps to determine the presence of smaller amounts of free gas. Emphysema of the abdominal parietes is pathognomonic if it occurs at an early stage before organismal invasion can play a part.

Indications for operation.—If, in spite of treatment, shock does not pass off and the patient's condition does not improve in all respects an exploratory laparatomy must be carried out without loss of time. The prognosis in these cases depends on two factors—(1) the extent of the injury; (2) the lapse of time between injury and operation.

The mortality in unoperated cases with perforation of the hollow viscera is exceedingly high. When operation is carried out, even if

* See also Enterectomy and Intestinal Anastomosis, p 1052.

delay has occurred and peritonitis is established, the case need not be regarded as hopeless. Although mortality is very much higher in late cases, success is occasionally attained even if the condition is desperate. This statement is particularly applicable in these days of antibiotics, penicillin, ready blood transfusion, etc., but none the less unwarranted delay in operating is always to be deplored. Lacerations and contusions of the solid viscera are also potentially very serious.

General considerations.—It is most important in all cases that the patient should be subjected to a careful general examination. Too often an obvious and perhaps gross lesion determines the attitude of the surgeon, whereas a more complete examination would show, it may be, the hopeless nature of some other injury or at least its great importance. Generally speaking, it is a mistake to operate during the period of profound shock which so often follows these injuries. If this cannot be overcome by ordinary routine measures, especially blood transfusion, then it is highly unlikely that any operative interference will be successful. The same applies, but to a lesser degree, to the consequences of hæmorrhage; unless the patient shows some evidence of recuperative power it probably means that the loss which has already occurred is too severe to permit of recovery.

It is most important that the manipulations of the surgeon should not be impeded in any way, and for this reason it is usually best to employ general anæsthesia.

The first principle which should guide the surgeon in the conduct of the operation is a thorough and adequate exposure. For general purposes nothing is better than a midline incision, but there should be no stint to its length. In the first instance the incision ought certainly to extend the whole of the distance from the umbilicus to the pubes, and it may very often with advantage be enlarged upwards as far as the costal margin. The surgeon should not hesitate either to make a second incision or to make a cross cut from the original incision if, by so doing, he can facilitate the manipulations which may be necessary as life-saving measures in difficult cases. After opening the abdomen it is essential to determine the full extent of the injuries, for that will help the surgeon to decide at the outset what measures to employ. For instance, an isolated laceration of the intestine may suggest resection with anastomosis as the ideal and safest method but should there be other associated lesions, such as multiple tears in the mesentery or injury to the spleen or kidney, it may be necessary to take the risk of simply suturing the torn bowel rather than excising the damaged segment. It is not necessary to display either brilliant or heroic operative procedures unless they will more safely tide the patient over a great emergency. The surgeon must also remember the wonderful reparative power of the peritoneum, especially in adolescents. When there has been bleeding into the peritoneal cavity it is wise to remove the larger clots but it is not necessary to attempt to clear out all the blood. In perforative lesions, where infection has already started,

an effort should be made to aspirate or mop up free blood in order not to leave ponds that might form abscesses later. It is in such circumstances that antibacterial therapy may be most helpful.

The real problems in wounds and bruises of the intestine are met when the injuries are multiple. In these circumstances it may be easy to remove the whole of the damaged bowel, but the surgeon must never forget that massive resection involving more than one-third of the intestine is likely to interfere permanently with nutrition·

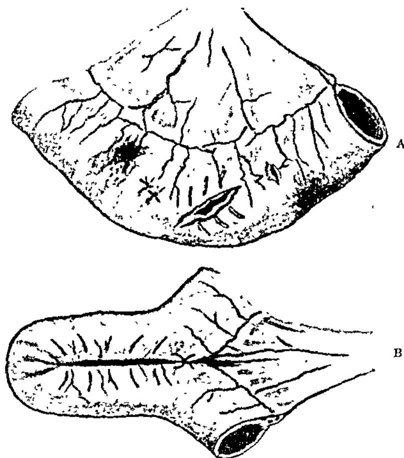


Fig. 314.—The piece of bowel in A shows multiple small tears and is much bruised. The tears are sutured and, as a further protection, the bowel is then folded on itself and tacked together as shown in B.

further, it may be that the surgeon must stay his hand because of the very serious condition of the patient It is remarkable how damaged and bruised intestine will recover if the areas involved are simply tucked in and overstitched. Sometimes a damaged piece of intestine may be sutured against an undamaged coil, the latter acting as an admirable graft. (Fig. 314.) This may be done even when the mucous membrane cannot be very securely sutured

Technique.—When shock is severe the skin preparation should be deferred until the patient is anæsthetized, and it should not be prolonged. If a differential diagnosis has been made, the incision should

be placed so as to give the best exposure Otherwise, the abdomen is opened in the mid-line from umbilicus to pubes. When the peritoneal cavity is reached, it is necessary to have a definite plan of action, so that no time may be wasted and nothing overlooked, this is determined by what is found on opening the abdomen; free gas or blood may escape. If blood only is found, and this is most often the case, examine in this order the omentum, especially at the greater curvature of the stomach, by direct vision, and the liver, the spleen, and the kidneys, by palpation. If no injury is located then the mesentery is examined, beginning at the ileo-cæcal region and working upwards. If the injury is not disclosed, the blood is mopped or aspirated out of the abdominal cavity and a further detailed search made—bladder, stomach, duodenum, pancreas. In civil life the small intestine is more often injured than the large, and both more often than the stomach. If free gas escapes, the surgeon picks up the small intestine at the ileo-cæcal junction and rapidly examines it from below upwards, the assistant returning the gut after inspection, so that only a small loop is exposed at a time. If no injury is found, the large intestine is examined from the cæcum, and when the transverse colon is reached the stomach and duodenum, and then the rest of the large gut. If there is extravasation of intestinal contents the injury is generally quickly discovered. It is curious how often the damaged segment of intestine is found in the neighbourhood of the incision.

INJURIES OF THE LIVER

If the diagnosis can be made with some confidence before operation, it will be possible to select the incision so as to obtain a wide exposure. The oblique incision of Kocher, as used for the surgery of the biliary tract (p 920), also provides adequate exposure. Some surgeons are in favour of a transverse incision through the right rectus abdominis at a level of 2 in. above the umbilicus; it gives an excellent exposure of the upper or lower surface of the right lobe, or of the gall-bladder and biliary ducts, and can, if necessary, be extended across the middle line or to the right as required. It is easily closed, and subsequent straining by vomiting or coughing does not tend to draw the edges apart as in vertical incisions. If the subumbilical exploratory incision has already been made, it will be necessary to extend it above the umbilicus, and perhaps add division of the upper right rectus abdominis muscle. A loin support, as used in gall-bladder operations, and the reversed Trendelenburg position are both useful adjuncts.

The usual indication for operation is hæmorrhage. If the hæmorrhage has ceased when the liver is exposed the injured area, unless extensive, should be left alone. If there is a wide laceration, with or without active bleeding, the raw surfaces should be approximated by catgut sutures deeply placed so as to coapt the surfaces as far as possible. Some difficulty may be experienced, as the liver is friable and stitches are apt to cut out. This is best met by using thick catgut which is passed beyond strands of the same material buried in the liver on either

side of the tear (Fig. 315). Tears difficult to expose may be packed with omentum held in position by one or two loosely tied sutures, the needle being guided by touch rather than vision.

If the liver is much contused, and sutures will not hold, the tears or lacerations which bleed should be packed with absorbable gauze (Oxycel, which is a ready sterilized oxidized cellulose preparation, absorbable gelatin sponge, "gel foam") or with pieces of muscle, e.g., from the rectus, or "gel foam". When ordinary gauze is used for packing the free end is brought through the abdominal wall and left for five to seven days, as early removal will very likely re-start the

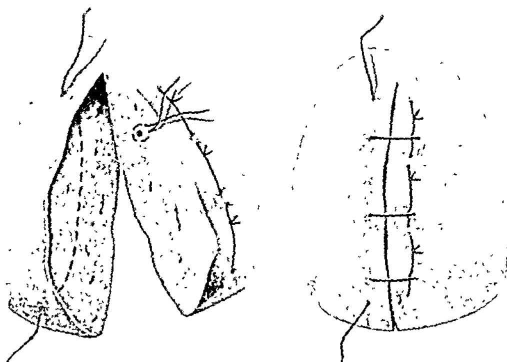


Fig. 315.—Suture of liver with a buried catgut strand to support the sutures of apposition.

On the left side of the wound the buried strand has been passed with a large half-curved needle; on the right the strand has been introduced in three sections on a fully-curved needle. On the cut surface is shown the method of surrounding an open hepatic vein with a purse-string.

hæmorrhage. Loose or sequestrated fragments of the organ, even if of considerable size, should be removed as they are likely to necrose and either cause a delayed fatality or keep up a sinus or septic focus for a long time.

Injuries to the *gall-bladder* and *bile-tract* are very uncommon. It is better treatment to remove a ruptured gall-bladder than to suture it, because there is certain to be some bruising of indefinite extent, and leakage may occur after suturing. Tears of the *common bile-duct* or division of that structure should be repaired by suture and drainage by a tube passed down to the site. In complete division repair gives much better results than delayed operation and every effort should be made to approximate the retracted ends and to unite them by direct suture. Intubation of any sort is better avoided.

For further details of operations for liver injuries, *see* p. 877, and for injuries of the ducts, p. 881.

INJURIES OF THE SPLEEN

The spleen is generally damaged in crushes with fracture of the ribs, and perhaps injury to other viscera. Severe internal hæmorrhage is the leading feature.

If a diagnosis is made, the incision should be planned as for splenectomy. A vertical incision through the left rectus from the costal margin to the level of the umbilicus will nearly always suffice. As a rule, the safest course is to remove a ruptured spleen, owing to the difficulty of controlling hæmorrhage by suture in an organ which is very friable and is made still more so by trauma (*see* p. 1005).

INJURIES OF THE PANCREAS

The pancreas is rarely damaged alone, though instances are recorded from crushes, gunshot wounds, and stabs. In the majority of cases other organs, especially the stomach, are injured at the same time, and the pancreatic injury is often not diagnosed before exploration. The operation consists in opening the abdomen in the median or paramedian supra-umbilical line, exposing the pancreas, and suturing the tear. Fine chromicized catgut on a round non-cutting needle should be used. The gland is reached by tearing an opening through the gastrocolic omentum and turning up the stomach, which may also be gently retracted upwards. Unless the splenic artery has been divided there is not usually great hæmorrhage. A stab or a bullet-wound may be closed by a purse-string suture, but a more considerable tear must be approximated by a series of interrupted sutures. When the injury has almost completely torn across the gland it will probably be best to remove the sequestrated caudal portion. In all cases the lesser sac must be drained, and if the pancreas is much lacerated or contused the drain, usually a softened rubber tube, should be brought from the vicinity of the injury. Gauze packing should be avoided whenever possible as its removal is so likely to produce pancreatic fistula. Oozing areas which cannot be controlled by suture may be packed with absorbable gauze. As Jordan Lloyd pointed out years ago* contusions and minor lacerations are frequently followed by inflammatory effusion which is localized to the lesser sac as the result of occlusion of the foramen of Winslow. This is one of the forms of pseudo-cyst of the pancreas. For cure of this condition drainage is essential. (*See* page 991)

INJURIES OF THE HOLLOW VISCERA

The stomach, owing to its comparatively sheltered position and the thickness of its walls is less often injured than the intestines. In both small and large bowel the portions most liable to injury are those which are least mobile—i.e. in the small intestine, the upper

* *Brit. Med Jour*, 1892, ii, 1053

rt of the jejunum and the lower part of the ileum and in the large estine, the cæcum and ascending colon. The splenic flexure, wever, which is the least mobile part of the large intestine, is well otected under the ribs and is rarely injured. In all cases the liability rupture is greater if the viscus is distended with gaseous or fluid ntents at the time of the injury.

It follows that most of these ruptures are of a bursting character m within outwards, and they are not infrequently multiple. In stomach the common site is the lesser curvature, in the intestine, antimesenteric border. In other cases the mesentery is injured d there is liability to hæmorrhage, to necrosis of the bowel owing the cutting off of the blood supply, or to perforative peritonitis he mesenteric tear extends into the gut.

Treatment.—In the **stomach** gross injuries rarely come to operation they are so frequently associated with laceration of the liver or een, and death occurs almost at once—as, for instance, in a buffer cident—or the patients never recover sufficiently from the primary ock to hold out the least prospect of success from intervention. At eration hæmorrhage into the peritoneum and the escape of gas on ndling the stomach suggest the site, and the wall of the viscus in the inity is seen to be much bruised. It is always wise to open the lesser by carefully tearing through the gastro-colic omentum, and if it ntains blood or fluid of any sort to make a careful search for an ury on the posterior wall. In the smaller ruptures it is always ssible to suture the rent It is not necessary to pare the edges less there is much laceration. The rent is closed by catgut suture ssed through all the coats, and this suture line is buried by a superposed continuous Lembert suture. If the rupture is quite small it y be closed by a purse-string. In extensive injuries it may be wise make a temporary gastrostomy as a last stage of the intervention. in the majority of these cases the stomach is not empty at the time rupture, it is well to provide a pelvic drain.

Isolated injuries to the **duodenum** are relatively rare, which is tunate, for the accident is very serious and attended by a high rtality. Sometimes the second part is ruptured and the tear may be ra-peritoneal *and associated with extravasation* with consequent lulitis, which rapidly spreads and is nearly always fatal. Very ely a localized abscess may follow and eventually lead to the formation of an extraperitoneal duodenal fistula. When the tear is intraitoneal the irritating contents of the duodenum are poured into *belly and a rapid peritonitis frequently* results. Tears of the odenum will probably be across the lumen and may be particularly ficult to repair because of extension into the retroperitoneal tissue e necessary suturing may so interfere with the lumen of the bowel t an accompanying gastro-enterostomy may be necessary.

Injuries that are entirely retroperitoneal are difficult to diagnose, the symptoms are anomalous. Pain in the right upper quadrant,

with rigidity, distension and vomiting, slowly develop. After twelve hours, or thereabouts, the general condition is often out of keeping with the physical signs, for the patient looks very ill and is obviously toxic, with an icteric tinge and higher temperature than is usual in abdominal cases. Even on opening the abdomen the condition may not be obvious. The peritoneum may appear almost normal or contain just a little clear fluid with a small amount of lymph near the injured part. There is retroperitoneal hæmorrhagic extravasation on the right side, extending into and around the meso-colon. The cellular tissue is œdematous and crepitant, and there may be some fat necrosis.

To expose this portion of the duodenum an upper paramedian incision of ample length is required and in big bulky patients or in any difficulty the surgeon should not hesitate to cut across the outer segment of the rectus. When the peritoneal cavity is opened, the stomach and colon are lifted up as in the early stages of gastro-enterostomy and an incision is made through the posterior fold of the meso-colon towards the right and, by blunt dissection and gauze stripping, the injured area is cleared. Care must be taken not to injure the colic vessels. Another good method of exposure is to incise the posterior peritoneum vertically for about three inches as it leaves the second part of the duodenum. The bowel can then be bluntly mobilized with the finger until its posterior surface is seen. It may be difficult to expose the tear for the purpose of repair but the laceration must be seen in its full extent before sutures are applied. The inner wall should be approximated by sutures passed mattress fashion, to invert the edges into the lumen of the bowel. A continuous suture is then run along the inverted edge to complete apposition along the whole tear. In spite of the absence of peritoneum, additional sutures of the Lembert type need not be passed on the outside if the mattress sutures are efficient. If the extraperitoneal tissues are grossly infected, drainage should be provided. For this purpose an incision should be made in the right flank down to the retroperitoneal space which is opened up towards the site of injury by blunt dissection with the finger, a rubber tube or strand being placed in the track.

When the rupture is at the duodeno-jejunal junction, the bowel may be torn so near its origin that it may be well nigh impossible to make an end-to-end repair. The best course to pursue under the circumstances is a matter of grave difficulty. Moynihan* boldly closed the proximal end of the duodenum and implanted the open end of the jejunum into the stomach so that all the bile and pancreatic juice had to regurgitate into the stomach before it could reach the intestine. The patient is said to have enjoyed perfect health until his death on the 104th day from perforation caused by the Murphy button used to make the anastomosis. But this method cannot always be relied on, and a very determined attempt should be made to restore the continuity of the bowel, even at considerable risk. It is usually possible to mobilize the proximal end from the retroperitoneal

* *Brit Med Journ*, 1901, i, 1136

bed into which it retracts and to make an end-to-end anastomosis. To assist the exposure the retracted ends of the proximal segment may be blindly caught in toothed forceps and gently but firmly drawn from its retroperitoneal position. A certain amount of room and freedom can be gained by the use of bowel clamps. If anastomosis cannot be done, the upper end of the distal jejunum may be implanted

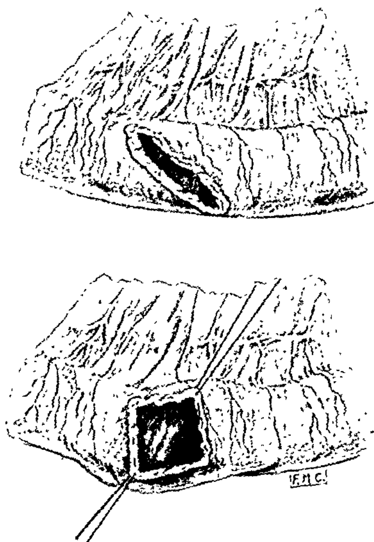


Fig. 316.—Rent in bowel sutured in transverse axis to avoid narrowing the lumen.

end on into the stomach and an end-to-side union made between the divided proximal end of the duodenum and the intestine leaving the stomach.

Intestinal injuries vary from a split in the serous or sero-muscular coats to a complete rupture of continuity. In partial ruptures, if the case is seen early, there is often surprisingly little extravasation because of the pouting of the mucosa through the rent and the temporary cessation of peristalsis.

Injuries of the serous and sero-muscular coats must be repaired by

suturing with fine chromic catgut or silk to prevent subsequent adhesions. At the same time a very exact examination must be made to exclude an injury to the mucosa, for severe bruising may lead to necrosis.

If all the coats are perforated and the amount of damage is small, little more than a puncture, a purse-string suture will suffice with perhaps one or two interrupted stitches over its peritoneal aspect. In larger tears or lacerations the rent should be sutured transverse to the long axis, so as to avoid constriction of the lumen. If the edges are ragged they may be trimmed up with scissors but formal excision is not necessary. For the closure (Fig. 316) a continuous all coats suture is employed, and this is buried by a Lembert suture.

If the injury is more extensive, and there is much laceration or contusion of the bowel-wall, it is usually much safer to carry out a

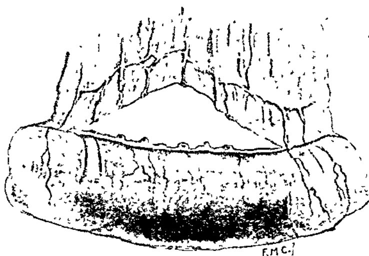


Fig 317 —Laceration of mesentery. Bowel torn away. Resection necessary.

resection and anastomosis than to suture a large rent. Particularly is this the case if the mesentery is injured, and it should be the rule that a generous rather than a minimal resection should be done. It is, however, true that suture has a much lower mortality than excision, and should be chosen whenever it will safely suffice.

A point of importance is the treatment of multiple ruptures. The problem arises, of course, more often in gunshot wounds than in civil practice. The surgeon must decide whether multiple resections should be done, or a single resection to include all the injured areas, or whether a combination of repair and resection is wiser. Time is necessarily a factor of real importance in dealing with injuries of such severity. It will take longer to make multiple resections, and unless the length of uninjured intestine which must be sacrificed is too great, it is better to do a single resection to include all the damaged intestine. But this is not always possible, owing to the distance between the ruptures, and multiple resections may be undertaken with confidence

if the surgeon is constantly doing *intestinal suture operations.* It is never good practice to sacrifice more intestine than is absolutely essential to ensure success. Many enormous resections have been carried out with recovery and little apparent interference with health,* but the converse is also true. Probably six feet is the limit beyond which it is unwise to venture.

In these cases it is essential to have a very free exposure and to examine the site of the lesion carefully. Sometimes a piece of bowel is completely separated from its mesentery over an area of several inches (Fig. 317), and in such circumstances resection must be carried out.

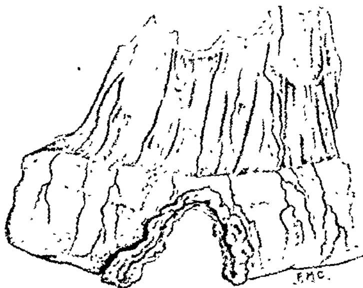


Fig. 318.—*Almost complete severance of bowel, but suitable for repair by suture.*

Very rarely a portion of the intestine may be torn loose from all its connections and may lie free in the peritoneal cavity and, unless discovered and removed, it remains a focus of serious infection likely to destroy life or to seriously jeopardize the good result of any other measures that may have been adopted. Experience of war casualties has taught great respect for the recuperative power of the small bowel, and when lesions are multiple the surgeon need have no hesitation in adopting what, in civil life, might be looked upon as timid conservative measures. It is much safer to tuck in many small rents and to overstitch doubtful areas than it is to engage in multiple resections or to sacrifice too large an area of intestine. (Fig. 318.) In extensive wounds suturing should commence at the extremities and finish about the middle of the tear. In this way awkward irregularities or pouching at the ends are avoided Of course, two separate sutures are employed, one at either end. Occasionally the bowel which has been patched in this way may look as if it would be a source of obstruction, but as a matter of fact this rarely occurs, as the channel

* Grey Turner, *Lancet*, April 3rd, 1937 (Labour complicated by thrombosis of the mesentery, resection of ten feet of small bowel—patient alive and in good health twenty four years later.)

is always bigger than it appears and, in any case, a very small lumen will suffice for the fluid contents of the small intestine. When there is real and anxious doubt the surgeon can add a small lateral anastomosis to his repair. Two small perforations may sometimes be conveniently converted into one, which can then be sutured in the transverse axis. (Fig. 319.) In finishing these cases, time should not be wasted in closing the abdominal wall in layers, and even in

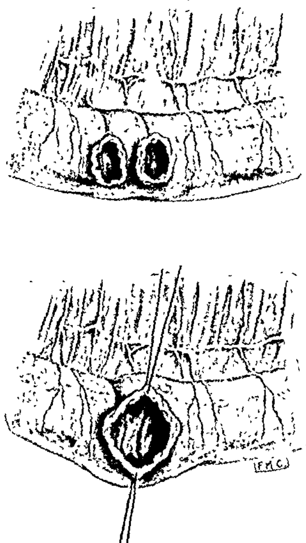


Fig. 319.—Two perforations converted into one and prepared for suture in transverse axis.

muscular subjects, through-and-through sutures of strong silkworm-gut or of silk are all that is necessary. In the after-treatment it is important not to be in a hurry to get the bowels to move, for bruised and damaged intestine should not be urged to activity by powerful purgatives.

Great difficulty and much added danger arise in injuries of the gut which have not a complete peritoneal covering, such as the greater part of the duodenum and some parts of the colon.

Retroperitoneal rupture in large intestine.—This condition is usually associated with other injuries such as laceration of the kidney. Even when it occurs alone, the patient very rapidly shows signs of retroperitoneal cellulitis. It is important to remember that, if an easy route to the surface is provided, suture of the bowel is not essential, and it may be much wiser to convert the wound in the bowel into a fæcal fistula by stitching its margins to the skin. Such a fistula may close spontaneously, or be assisted later by temporary proximal colostomy, or it may require direct interference for operative closure as in some cases of colostomy (*see* p. 1087). Even if satisfactory suture can be made, a drainage track to the surface should always be provided, as leakage often occurs, and is sometimes not recognized until the appearance of cellulitis or a localized abscess. After drainage, a fæcal fistula often occurs, this may close spontaneously in two or three weeks or months, or an extensive resection may be required.

RUPTURE OF THE URINARY BLADDER

Intraperitoneal.—These ruptures occur from direct blows or falls on the abdomen when the bladder is full. The tear is usually situated on the postero-superior surface. The accident usually happens quite apart from injuries to the pelvis, and indeed when the bladder is torn as the result of fracture of the pelvis, the rupture is generally extraperitoneal.

The diagnosis is readily made from the characteristic symptoms of shock, hypogastric pain and tenderness, frequent desire with inability to micturate, the evidences of increasing peritoneal irritation with signs of fluid in the flanks and the withdrawal of only a small quantity of blood-stained urine by catheter. It is significant if the desire to micturate passes off; confirmation may be obtained by cystography or the careful injection of 10 oz. saline, only a small proportion of which can be withdrawn.

Treatment.—Laparotomy should be carried out as soon as possible. A vertical incision is made in the midline below the umbilicus, the peritoneal cavity is opened, and blood and urine are swabbed away or removed by the suction apparatus If the tear is not obvious it may be found by the fingers passed down behind the viscus. When the rent is low down on the posterior surface the patient should be put up in the Trendelenburg posture, which greatly facilitates repair. Two guide sutures are inserted, one on each side of the rent, taking up the serous and muscular coats only, and these are used to lift the bladder towards the incision. These guides are a great aid to exposure and may render an otherwise difficult intervention comparatively easy. The rent is closed by catgut sutures, silk should not be used, for it tends to work loose into the bladder cavity where it may form the nucleus of a calculus If necessary, very frayed edges may be trimmed Two layers of suture should be employed, the first takes a good hold of the bladder-wall but does not penetrate the mucous membrane, the second

should be a continuous stitch on the peritoneal aspect. Sometimes it is very difficult to close a rent securely when it is situated low down on the posterior wall, or there may be so much bruising and hæmorrhagic infiltration that the closure is uncertain. In such circumstances a rubber tube should be placed in the recto-vesical pouch and brought out at the lower end of the abdominal incision, the patient being nursed in the semi-Fowler position for the first few days. In any case a catheter should be passed *per urethram* for continuous drainage and should be left *in situ* for a week. Each morning and evening the lumen should be gently irrigated to keep it free from blood at first and later from mucus or phosphates.

Results.—Here again, the time limit is the most important factor. If the operation is done in the first twelve hours the mortality should not be above 33 per cent., but after that time there has been a mortality of about 70 per cent. With the resources of the antibiotics and blood transfusion this should be much lower in these days.

Extraperitoneal ruptures are much more likely to be associated with fracture of the pelvis. In these cases there is considerable hæmorrhage as well as extravasation of urine into the pelvic cellular tissue, and this gives rise to local swelling above the pubes and either inguinal ligament. A few hours after the injury, such swellings are associated with marked blood discoloration. But unless the lesion is also intraperitoneal there is no peritonitis, though there may be considerable meteorism. Sometimes it is difficult or impossible to guide a catheter into the bladder, and in these circumstances the viscus has probably been torn away from the upper surface of the triangular ligament and the prostatic urethra completely divided. In the intraperitoneal variety, fluids can very readily be injected, for they pass through the rent in the bladder into the peritoneum, whereas in this variety more urine may be drawn off, but attempts to inject the bladder give rise to great pain and increase the suprapubic swelling. This injury also demands prompt operation. A mid-line incision is made above the pubes, not deliberately opening the peritoneal cavity. The extravasation of blood and urine becomes apparent as soon as the muscles are separated It is then necessary to remove the clots, after which the rent in the bladder may be seen or felt, though it may be very difficult of access. Should it be easily seen it can be closed by suture, but this is not essential and free drainage to the surface is all that is really necessary, though suture may shorten convalescence. When the bladder has been torn away from the triangular ligament, it is essential to secure alignment of the divided ends with as near approximation as possible though actual apposition and suture are not necessary. A catheter should be passed *per urethram* and guided into the bladder along the prostatic urethra by the surgeon's fingers working from the abdominal incision in the space of Retzius. By this means the prostate may be approximated to its normal position at the back of the triangular ligament and fixed there by one or two strong catgut

sutures. The catheter also ensures that the alignment of the urethra is accurate. If this plan is not successful two other methods are available. A silver catheter or a bougie may be passed through the rent in the bladder, or through an incision in that viscus made for the purpose, by the retrograde route until the end presents in the space of Retzius. The end of a rubber catheter which has been passed into this space *per urethram* is then cut off and its open lumen thrust on to the extremity of the solid instrument which has been passed retrograde fashion. The latter is drawn into the bladder carrying the rubber catheter which is then released. A stout catgut suture is passed through the edge of the divided prostatic urethra securing a good hold and then on through the catheter and is tied not so firmly as to cut through. When this rubber catheter is pulled on, as it leaves the penis it will draw the prostate down to its position on the upper surface of the triangular ligament. To maintain this position it may be necessary to put a stitch or two between the prostate and the ligament or to fix the catheter to the thigh or to attach a light extension to the instrument. The other plan is to pass a Foley catheter through the prostatic urethra by the retrograde route and to thread it on to the end of a solid catheter or bougie passed along the urethra until its point appears just above the triangular ligament. The Foley is then withdrawn *per urethram*, the bag is distended and traction made and maintained by one of the methods customarily employed.

Even when it has been possible to suture a rent and to pass a catheter into the bladder, it is essential to leave an ample suprapubic drain in the cellular tissue. If there is any possibility of an associated intraperitoneal lesion, this can be demonstrated by a finger passed into the bladder (through an incision if no tear exists) and through the rent into the peritoneum. In these circumstances the abdominal incision must be enlarged so that the peritoneal surface of the bladder can be inspected It may also be necessary to open the peritoneum if the question of some associated injury to other viscera arises. In late cases infection may already have occurred, and in these circumstances it is only essential to remove clots and débris and to provide ample facilities for drainage. During convalescence the patient should be treated in the Fowler position.

Results.—When free drainage is provided, the prognosis in this type of injury is good so far as life is concerned When the prostatic urethra is severed a troublesome stricture or deviation may develop and there is a tendency to a recurrent suprapubic fistula.

GUNSHOT WOUNDS OF THE ABDOMEN IN WARFARE

The war of 1914–1918 provided a wealth of material for the investigation of gunshot wounds of the abdomen, and much was written on the subject Towards the latter part of that conflict there was general agreement on the principles of treatment, and in analysing

965 cases, Sir Cuthbert Wallace* added to the work previously done by the late Sir George Makins. Speaking generally, it was accepted that the expectant treatment which was the rule after the South African War had given place to operative measures, and much of the success attending these interventions resulted from the early treatment in advanced operation centres (C.C.S.), and from the creation of abdominal hospitals. In the mobile warfare of the 1939–45 campaigns, and among air-raid victims, abdominal wounds seemed to be less frequent. The mortality, in the cases recorded, was admittedly high, because of the great difficulty of bringing the injured to operation centres within a reasonable time. When circumstances have made it possible to carry out the principles of treatment established in the war of 1914–18 the results have been comparable. Gordon-Taylor† found that the general recovery rate of abdominal cases submitted to operation was between 50 and 60 per cent. and in the Normandy invasion "attained the magnificent figure of 70 per cent."‡ With the exception of the large bowel, the recovery rate was rather higher than in 1914–18. He states§ that blood tranfusions and chemotherapy proved of great value.

Under the system which evolved between 1914 and 1918 most cases arrived between six and ten hours after injury, and statistics proved that while up to six hours the chances were in the patient's favour, after that period they were always against him. The limit of success was thirty-six hours in cases requiring resection of the small gut or suture of the stomach or colon. In both wars hæmorrhage was the chief cause of early death, and peritoneal sepsis later. Side-to-side and oblique wounds were more dangerous than antero-posterior, and wounds from the back more dangerous than wounds from the front. A special danger lay in buttock wounds penetrating the abdomen, and wounds of the descending were more dangerous than those of the ascending colon, owing to the former being in contact with the small intestine, which was often injured simultaneously.

The order of frequency of wounds of the viscera was found to be: (1) small gut, (2) colon, (3) liver, (4) stomach, (5) kidney, (6) spleen, (7) rectum, (8) bladder, (9), pancreas.

Abdominal wounds in warfare must always be among the gravest of injuries even when treated under the most favourable conditions. In the 1939–45 war the considerable improvement in results was accounted for by better pre-operative measures for resuscitation, especially blood transfusion, better and more complete resources at the time of operation, and much more enlightened after-care and nursing. Ogilvie‖ gives an excellent account of abdominal wounds in the Western Desert and his valuable paper should be studied by all called upon for war service.

* Lettsomian Lectures to the Medical Society of London, 1917 [illegible] *Journ. Surg.*, April, 1917, iv, 679

† [illegible]

‡ [illegible]

§ [illegible]

‖ [illegible]

Indications for operation.—It is well to wait an hour or two after admission before operation is carried out. The patient has time to recover from the journey, shock can be combated, and a better idea obtained of the necessities of the case and the scope of the operation required. The *pulse* is the best guide; a rapid pulse, of 120 or over, which does not fall, is a direct indication for intervention Very few patients whose pulse-rate is over 120 recover, though the mortality has been much reduced by preliminary blood-transfusion. *Vomiting* is of less significance. *Rigidity* is very constant, but may occur in thoracic injuries. *Hæmorrhage*, though surmised, often cannot be diagnosed with certainty unless in great amount, and *pain*, while constant, varies much in degree; extreme pain with board-like rigidity nearly always means an intestinal wound. If the abdominal wall is penetrated, a viscus is probably injured, and exploration is imperative, but admittedly it is not always easy to be sure. Emphysema of the parietes at an early stage, i.e., before gas-forming organisms could be the cause, is a sure sign of perforation of a hollow viscus. Experience and the views held by the surgeon must decide the question of operation. It should be remembered that " the bolder surgeon will get the worse operative mortality ", though he will have the satisfaction of saving a few desperate cases.

Operative technique.—Speed in operating is important, but it must not be at the expense of efficiency. The surgeon must know just what to do and must be systematic in carrying out his work. Exposure is all-important, and, generally speaking, the primary incision should be in the middle line. On opening the abdomen the first indication is to arrest hæmorrhage; its origin from the omentum or the mesentery may be obvious or welling-up from either flank may suggest the liver or the spleen as its source. But wherever its origin it must be found and dealt with at its source. Similarly, a perforative injury may at once declare itself, otherwise the intestine must be systematically searched Retro-peritoneal injuries are easily overlooked, but a hæmatoma behind the peritoneum, especially if crepitant, means a perforation which may be of the duodenum or some part of the large bowel.

General notes.—A suction apparatus is most helpful but not essential and in any event it must not be too powerful. For ligatures thread is more reliable than catgut and easier to manipulate. Mass ligatures are to be avoided, they often inadvertently include important vessels and may cut off essential blood supply, the occlusion of the actual bleeding point must be the aim. The local use of the sulpha drugs may be overdone, sulphadiazine is probably the most satisfactory but even it should not be used in profusion. In most cases provision for drainage should be made, there may be nothing to drain but a direct track to the surface provided by a softened rubber tube or a rubber strand is often a valuable safeguard Parietal incisions should be securely closed with through-and-through sutures of non-absorbable material—silk and silk-worm gut are hard to beat.

After-care begins as the patient leaves the table. Blood and plasma are valuable but supplies are not inexhaustible. The general fluid requirement is about 8 pints in 24 hours and water is to be regarded as the basal standard. Gastric suction is valuable and often essential until the return of normal peristalsis. The sooner natural drinking and feeding can be started the better. Abdominal cases do not transport well and if possible should not be evacuated sooner than ten days after operation.

Stomach.—Operation should be done in all cases through a median incision. It is not necessary to excise the wounds. In uncomplicated cases the mortality in Wallace's series was 5·27 per cent.; in complicated cases, 77·8 per cent.

Small intestine.—The abdomen is freely opened by a median incision. Blood is mopped out and hæmorrhage controlled, if considerable it may be from liver or spleen and demand attention as the first step. The small intestine is rapidly examined from the ileocæcal valve upwards, the gut being returned to the abdomen as each fresh section is withdrawn. If a small wound is found it is sutured at once, provided the bowel for 6 in. on each side is healthy. A better plan is to mark each wound with a suture left long and clipped, or a forceps left *in situ*, so that when the exploration is complete they can easily be identified for subsequent closure. The search continues, and similar small rents may be treated in the same way irrespective of their number (twenty small tears with perforation were sutured in one case with recovery, S. E. Duff). If a severe laceration of the intestine or mesentery is found, it should be wrapped in warm gauze until the exploration is finished.

The stomach is then examined, and lastly the colon. It is the exception for extravasation to occur in injury of the small gut, though common in large-gut wounds under war conditions when the bowels have so often to be neglected. If laceration, either of the gut or of mesentery, is considerable, it may be necessary to resect, but this increases mortality, and it is better to repair the injury by suture whenever possible, even if it causes narrowing of the gut.* End-to-end or lateral anastomosis may be used, but end-to-end anastomosis is perhaps more often performed and is generally regarded as best. Primary short-circuiting has been abandoned. Drainage is unnecessary.

The mortality in Wallace's series of uncomplicated cases was 65·9 per cent.; in complicated cases, 74·1 per cent. and in the recent campaign the corresponding figures were about 50 and 60 per cent. Injury to the duodenum was more fatal than injury to the ileum, and this more fatal than injury to the jejunum.

Large intestine.—A median or paramedian incision is the most suitable, because of the probability that the small intestine is also

* Owen Richards's later writings (1918). Fraser and Drummond (80 per cent. mortality in resection; 50 per cent. in suture), Walters and Lockwood agree, but F. Gordon Bell of [illegible] rate in 30 [illegible]

injured. This is especially likely in wounds of the descending colon. Where a diagnosis of injury to the hepatic or splenic flexures is made, it is better to make a transverse incision as this allows easy access to the liver, kidney, and spleen which are often involved In the transverse colon the wound should be sutured if possible, and if that cannot be done the tears may be converted into an artificial anus, or the battered bowel may be resected and the opened ends fixed in the parietes. Primary resection with anastomosis is rarely successful in wounds.* In the ascending and descending colon the position is complicated by the possibility that the wounds may be retroperitoneal; to gain access it may be necessary to mobilize the bowel as is so often done before an ordinary resection.

In the last campaign it was generally admitted that the exteriorization of colon injuries was a great step forward in their management. The principle applies to all large bowel injuries, and includes bringing out a loop of torn or much contused bowel to be fixed outside or excising portions of bowel, the open ends being left on the surface like a double colostomy. In the latter event it is a considerable help in the subsequent closure if the limbs of the loop have been sutured together over a distance of two inches. A severely bruised and probably devitalized portion of bowel should be treated as though actually torn as there is great risk of subsequent necrosis.

It must be remembered that this plan commits the patient to a later intervention which is not without its own risk. A retrospective view showed that wounds of the right colon were amenable to repair by suture or resection with encouraging results, but that for the left colon exteriorization held out the better prospect. When large bowel is repaired but not exteriorized a proximal colostomy should be made.

Rectum.—The rectum may be injured by buttock wounds or wounds fracturing the pelvis. The great risk is pelvic cellulitis with septic absorption. Wallace was in favour of transverse colostomy, and the value of this was fully established in the recent campaign. Posterior drainage of the cellular tissue is also very important. In one series of 21 cases only 7 recovered and with all aids the mortality remains high, probably 50 per cent.

Liver.—If no other organ is injured, gunshot wounds of the liver are best left alone. If hæmorrhage makes operative interference imperative the wound in the liver should be either sutured or packed (*see* p. 763).

Spleen.—The spleen should be exposed by a left subcostal or rectus incision. If hæmorrhage has ceased the organ may be left alone. Gauze packing will sometimes suffice to stay hæmorrhage from the outer surface. Splenectomy should be done if the organ is much lacerated or its vessels injured. The mortality in uncomplicated cases was 50 per cent. ; in complicated cases, 63 6 per cent.

Kidney.—An incision should be made in the loin and the wound

* Naunton Morgan, *British Journal Surgery*, xxxii, No 127, Jan, 1945.

sutured or packed and drained. The organ should be excised only if the injury is very severe. The mortality was 18 per cent.

Pancreas.—This organ is seldom injured alone; the stomach is usually involved. Severe wounds are rapidly fatal; lesser injuries are usually complicated by local inflammation and drainage is essential.

Bladder.—Gunshot injuries may be intraperitoneal, extraperitoneal, or both, and in almost half the cases they are complicated by wounds of other viscera, generally small intestine. Intraperitoneal wounds are, as a rule, easily sutured, and suprapubic drainage is unnecessary, but a catheter should be retained for at least four days In extraperitoneal wounds suprapubic drainage of the bladder is usually wise and drainage must be provided for the extravesical cellular tissue. The mortality in uncomplicated cases has been 50 per cent. or more mostly from shock and hæmorrhage and late sepsis, but with the additional aids now available is improving.

GUNSHOT WOUNDS IN CIVIL LIFE

These are usually caused by small arms or by shot-guns and often at short range. In the circumstances there may be great damage to the parietes as well as to the abdominal contents. Shot-gun pellets may be scattered in all directions and the wad may lodge in the abdomen. The latter must be removed, as it will almost certainly be associated with infection and may cause peritonitis or keep up a sinus for years, but it is not necessary to trouble about the small shot as long as any visceral lesions are attended to. All that has been said about abdominal injuries in general and gunshot wounds in warfare apply to those in civil life, but there is the advantage that, as a rule, surgical aid is summoned much earlier and can be carried out in more suitable surroundings It is essential to work with ample incisions and to make a very thorough and complete investigation before the first discovered injury is dealt with. The lesions are frequently multiple and one overlooked may completely spoil the result of an otherwise brilliant piece of surgery.

Both in war and peace the intelligent use of restorative measures like blood transfusion and antibacterial therapy are admittedly most helpful, but these measures can only supplement and do not replace the application of sound surgical principles in the management of the injury.

CHAPTER XV

OPERATIONS ON THE STOMACH AND DUODENUM

By NORMAN C. TANNER

It is impossible to describe operations on the stomach and duodenum with any finality. New operations and techniques appear, advances in the sister sciences, particularly in those of anæsthesia and pharmacology, expand the field or diminish the need for surgery. Even the diseases themselves appear to change in character and frequency. By careful analysis of the results of the various operative

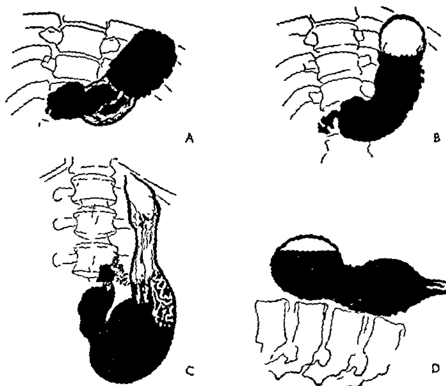


Fig. 320.—The stomach contour as seen by X-ray.

A, Transverse or "steerhorn" stomach (recumbent) B, The same in the upright position. C, Long or "J" shaped stomach in the upright position. D, Lateral view of stomach (recumbent)

procedures, their relative merits may be assessed. Some operations may be judged too dangerous, bearing in mind the lesser hazard inherent in the condition treated, or too ineffective to justify the risks of surgical intervention, and so must be discarded. Others have proved effective and valuable, but final judgments on the relative advantages of rival methods of treatment, as for instance partial gastrectomy or vagotomy in the treatment of duodenal ulceration, cannot yet be made

Anatomical and physiological considerations.—At one time much stress was laid upon the shape and position of the stomach, detailed descriptions being given of the various divisions of the organ and the relations of these divisions to surrounding viscera. Such divisions are largely artificial, the stomach being a hollow muscular viscus which continually alters its shape and position* according to the volume of its contents, the tonus and peristaltic action of its walls, the phase of respiration, and the position of the body.

There is also some variation in the shape and tonus of the stomach in different individuals varying from a rather transverse " steerhorn " type of stomach to a " J " shaped stomach, the greater curve of which may lie in the pelvis (Fig. 820).

During an operation differentiation between fundus, body, pyloric antrum and canal is not apparent.

The stomach, the first part and half of the second part of the duodenum are covered with peritoneum anteriorly. Behind the stomach and first segment of the first part of the duodenum lies the lesser sac of peritoneum, separating the stomach from the pancreas, mesocolon and duodeno-jejunal junction. In adult life, however, the lesser sac is often in part adherent and obliterated, so that the part of the mesocolon containing the middle colic artery may be fused with the gastro-colic omentum or with the posterior wall of the stomach, the gastro-epiploic and middle colic vessels being lightly adherent and only a centimetre or so apart—a point to be born in mind when either of the vessels require ligation. Just below the entrance of the œsophagus on the posterior wall of the stomach is an area uncovered by peritoneum which extends downward to the level at which the left gastric vessels pass from the cœliac artery to the lesser curve of the stomach. On either side of this narrow unperitonealized area is a double peritoneal fold passing from the posterior wall of the lesser sac to the stomach, forming a ligament sometimes called the " falx coronarium " because of the presence of the coronary or left gastric artery near its lower edge.

Blood supply.—The stomach is richly supplied with blood by vessels which ramify mainly in the submucous coat. The vessels of the stomach consist in the main of two vascular arches running along the greater and lesser curvatures. That on the lesser curve is formed by an anastomosis between the left gastric or coronary artery arising from the cœliac axis and the right gastric artery arising from the hepatic, while the arch on the greater curve is formed by the right gastro-epiploic branch of the gastro-duodenal artery and the left gastro-epiploic arising from the splenic artery.

The two arches so formed lie closely applied to or embedded in the lesser curvature and about half an inch distant from the greater curvature respectively, and from them a large number of branches are given off at right angles to pass to the anterior and posterior surfaces

* A. E. Barclay, *Brit. Med. J.*, 1910, vol. ii, 537, and "The Digestive Tract," Cambridge University Press, London, 1933.

of the stomach (Fig. 321). From the left gastric artery also arises an ascending branch which passes upwards to give branches to the cardiac end of the lesser curvature and then anastomoses with the œsophageal vessels. From the splenic artery near its termination several vasa brevia pass in the gastro-splenic omentum to supply the upper part of the greater curvature of the stomach. In addition one or more vasa brevia may leave the splenic artery near the middle of its course and pass directly upwards behind the lesser sac, finally arching forwards to supply the highest part of the greater curvature near the incisura cardiaca.

The first part of the duodenum is supplied by branches from the

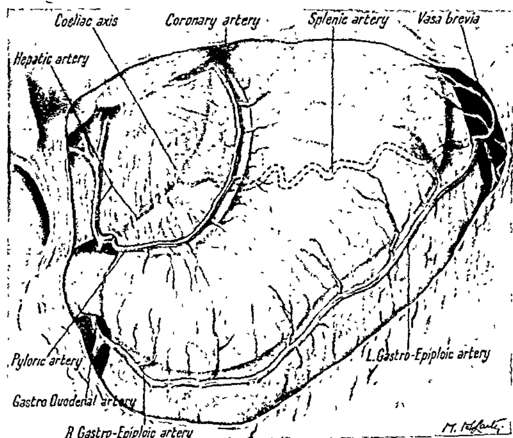


Fig. 321.—Blood supply of stomach.

right gastric artery to its upper surface and by branches from the superior pancreatico-duodenal artery to its posterior and lower surface.

Many variations in the classical origin and distribution of these arteries may occur. An occasional anomaly of importance during the performance of gastrectomy is the origin of a large branch from the left gastric artery which crosses the gastro-hepatic ligament to the liver. This may be an accessory left hepatic artery, but on the other hand it may represent the main systemic arterial supply to the left lobe or even to the whole of the liver—in other words it may be an anomalous left or main hepatic artery.

Lymphatic distribution.—The disposition of the lymphatics of the stomach influences the extent of the resection required when it is performed for carcinoma. The lymphatic vessels of the stomach form subperitoneal and submucous plexuses which communicate freely with each other. There is free communication between the gastric and œsophageal plexuses across the cardia. At the pylorus the communication is much less free, there being usually some subperitoneal anastomoses between the stomach and duodenum but little if any in the submucous space.* The direction of the lymphatic flow corresponds roughly to the venous drainage. The lymph nodes of the lesser curve form two groups. The lower accompanies the descending branch of the left gastric artery and drains the lesser curve of the stomach and pyloric region, the higher is a chain of glands round the cardia, the paracardial glands, draining the œsophagus and upper stomach. From these two groups the drainage is to a group of nodes round the stem of the left gastric artery, and from here their efferents pass to the cœliac group of pre-aortic lymph nodes. A group of nodes accompanies the gastro-epiploic arch (though sometimes they stray downwards in the great omentum) and drain the corresponding part of the greater curve of the stomach. Their efferents pass to the subpyloric group of nodes—which lie close to the duodenum round the bifurcation of the gastro-duodenal artery, and the subpyloric nodes drain to the pre-aortic group though some may communicate with the superior mesenteric nodes.

The vessels from the fundus and upper greater curve of the stomach drain partly to the paracardial nodes, but mainly to the pancreaticolienal group of nodes which lie in the gastro-splenic omentum and above and posterior to the tail of the pancreas † Their efferents drain to the middle suprapancreatic nodes and thence to the cœliac group of pre-aortic glands (Fig. 322).

Nerve supply.—The nerve supply of the stomach is derived from sympathetic and vagus nerves. The sympathetic supply reaches the stomach from the cœliac plexus via the fibres round the left and right gastric, gastro-duodenal and splenic arteries, and is derived from the 6th, 7th, 8th and 9th thoracic spinal nerves.

The parasympathetic or vagal fibres are of practical importance to the surgeon and although they vary considerably in detail, they tend to conform to a common pattern in the majority of cases.‡ At the level of their crossing by the main bronchi the two vagi lie antero-lateral to the œsophagus Just below each divides into anterior and posterior branches, the two anterior branches unite and the posterior branches unite to form anterior and posterior œsophageal plexuses. From these plexuses at a distance usually between one and three centimetres above the œsophageal hiatus anterior and posterior gastric nerves are formed One or both nerves may be single trunks, but in

* R T Horton, *Am J Anat.*, 1928, xli, 197

† J K Jamieson and J F Dobson, *Lancet*, April 20, 1907.

‡ I A Chamberlain and T Winship, *Surgery*, 1947, ii, 1.

40 per cent. of cases one or both have secondary nerves running with the main nerve. At about the level of the cardia each nerve divides

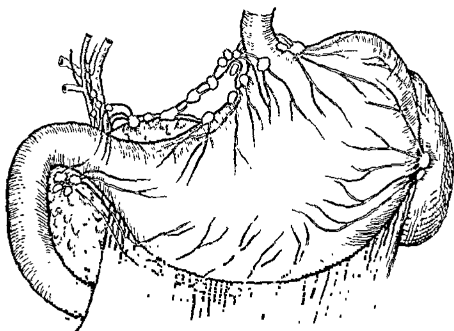


Fig. 322A.—The lymphatics of the stomach after Jamieson and Dobson The anterior surface.

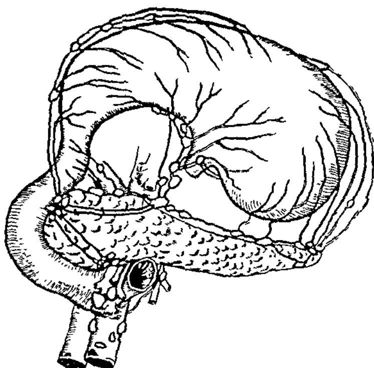


Fig. 322B.—The organ is turned upwards to show the posterior surface.

to give branches to the body of the stomach, branches which course along the lesser curve to supply the stomach and in addition the

anterior sends a branch towards the hilum of the liver and the posterior sends a branch towards the cœliac artery. From both these latter branches some fibres may return to supply the stomach.*

Physiological considerations.—From the surgical point of view the most important physiological functions concern the secretion of acid, and the anti-anæmic factor. Peptic ulceration in nearly every case depends on the secretion of acid, and operations for its cure are designed to reduce the acidity or to deflect the acid juice from the ulcer site. The acid secreting cells of the peptic glands of the stomach extend roughly two-thirds of the way from cardia to pylorus,† while the glands of the distal third of the stomach or pyloric glands secrete a weakly alkaline juice in smaller quantities (Fig. 323).

The secretion of acid gastric juice is stimulated by vagal impulses. The vagus is not only responsible for the psychic or cephalic phase of gastric secretion—the secretion which occurs at the sight, smell or taste of food—but is in part responsible for the basal day secretion of acid which occurs independently of meals and the maintenance of the night secretion.

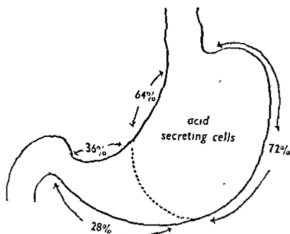


Fig. 323.—The extent of the acid secreting cells of the stomach (after Radasch).

There is considerable accumulation of experimental and operative surgical evidence to show that there is an internal secretion (gastrin) produced by the pyloric part of the stomach which stimulates the fundus and body to secrete acid.‡

In addition the stomach and possibly other organs elaborate an enzyme which unites with certain proteins in the foodstuffs to form an anti-anæmic factor. This substance appears to be absent in sufferers from pernicious anæmia High gastrectomy does not lead to the development of hyperchromic macrocytic anæmia, apart from a few scattered instances which may have been coincidental. This is probably because the stomach is not the only source of the anti-anæmic intrinsic factor. Total gastrectomy is followed a few years later by macrocytic anæmia in a significant proportion of the cases. Minor and occasionally severe forms of microcytic anæmia may occur after partial or total resection of the stomach, but this is probably due to interference with the absorption of iron.

CONGENITAL PYLORIC STENOSIS

In this condition the muscle of the pylorus is twice or more times its

* R. G Jackson, *Arch Surg*, 1948, lvii, 333. † Radasch, *Internat J. Gastroenterology*, 1921, i, 28
‡ J S. Edkins, *J. Physiol.*, 1906, xxxiv, 133.

normal thickness, the hypertrophy mainly involving the circular fibres. The thickening takes place at the expense of the lumen so that the outside circumference may not be much altered though there is usually an obvious enlargement. The lumen is greatly narrowed and the mucosa in the pyloric canal is thrown into longitudinal folds thus adding to the obstruction The hypertrophy ceases abruptly at the duodenum but the tumour fades off more gradually on the gastric side There is some compensatory hypertrophy of the muscular coat of the whole stomach, and gastritic changes in the mucosa.*

The cause of the condition is unknown. Histological examination reveals œdema of the muscle fibres It occurs about once in every two hundred children in Britain, is commoner in males than females in a proportion of four to one, and the firstborn is the most susceptible. The condition has been found in the fœtus and there is a possibility



Fig. 324 —Congenital pyloric stenosis before operation. Age 4 weeks; weight 7 lb. Birth weight 8½ lb. (Sir James Walton's case.)

that minor forms of the disease may persist but may not produce symptoms until adult life (*see* Pyloric Hypertrophy of Adults, p. 867).

Clinical picture.—The infant usually appears normal at birth. The earliest symptom, regurgitation of part of the feeds, usually appears during the second or third week of life, but may be delayed for twelve weeks or more. Vomiting shortly after feeds occurs later and increases in amount until most of the food is returned, the vomited material being forcibly ejected Retching does not occur, and nausea is probably absent for the child will resume feeding shortly after vomiting. The vomitus consists of undigested or partially digested milk and does not contain bile The baby becomes constipated, loses weight, and later becomes dehydrated with wrinkled inelastic skin and sunken eyes (Fig 324).

* D Levi, *Overseas Post Grad Med J*, 1950, iv, 365

On examination, loss of subcutaneous fat and signs of dehydration may be present. With the child warm and taking a feed, and in a good light, the abdomen is inspected. The lower abdomen may be flattened, but the upper abdomen is distended as a result of gastric dilatation. That the dilatation is gastric may be confirmed by observing waves of peristalsis passing from left to right. On careful palpation to the right of the upper rectus muscle, a deeply placed mobile mass, the thickened pylorus, may be felt in nearly every case.

Radiological examination.—In doubtful cases, X-ray of a barium or lipiodol meal may be made. The barium is almost completely retained

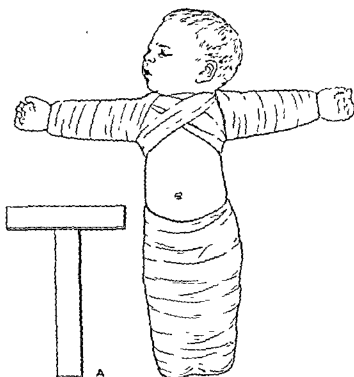


Fig. 325.—Infant bandaged to T-shaped splint to immobilize the limbs.

in the stomach for six hours or more except for that which may be vomited The pyloric canal is shown narrow and elongated.

Indications for operation.—If medical care does not result in early definite improvement, surgery should be undertaken without delay.

Operation.—At one time gastro-enterostomy, pyloric divulsion and even pylorectomy were performed for the relief of the condition, but these operations, so dangerous in infants, have been entirely replaced by the simple pylorotomy usually associated with the name of Rammstedt This operation can be carried out rapidly, has a very low mortality and gives most satisfactory results.

Preparation for operation.—It is unwise to treat these cases as acute emergencies and time should be taken to correct dehydration

and malnutrition by parenteral saline, or intravenous isotonic glucose in saline. The stomach is emptied by aspiration and if there is much debris it may be washed out with saline just before operation. Before transit to the theatre the infant is warmly wrapped and fixed to a T-shaped splint to immobilize the limbs (Fig. 325). It is most important to keep the infant warm during operation.

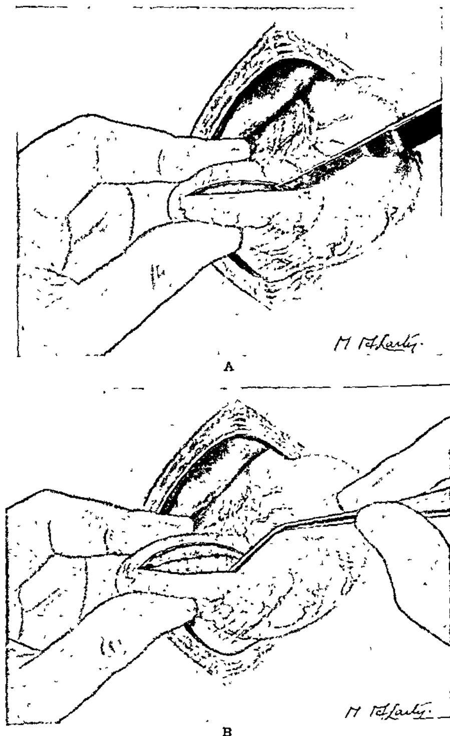


Fig. 326—Rammstedt's operation. A, Incision of peritoneal coat. B, Division of muscle with blunt dissector.

Anæsthesia.—Either local or general anæsthesia will be found satisfactory. The abdominal wall is infiltrated down to the peritoneum in the line of the proposed incision with procaine half per cent. and 1/200,000 adrenaline in saline; 10 c.c. of this solution is usually more than sufficient. During the intraperitoneal manipulations it is well to give the child some sugar enclosed in gauze to suck.

Operative technique.—A high incision is made through the middle of the right rectus muscle, extending from the costal margin downwards for about 2½ inches. The anterior rectus sheath, the rectus muscle, and the peritoneum are divided in the same line, for it is difficult to displace the rectus muscle without damage in infants. It is found that the liver presents in the whole length of the incision, indeed the object of this high incision is to use the liver as a barrier to prevent extrusion of the bowel when the child coughs or strains. Great care should be taken to arrest all bleeding.

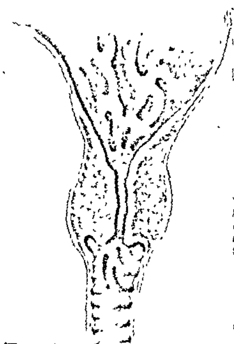


Fig. 327.—Diagram of section through pyloric region in case of congenital hypertrophy.

A finger is introduced into the wound and the presence of the pyloric hypertrophy is confirmed. With non-toothed forceps or the fingers, a part of the pyloric end of the stomach is withdrawn from the wound. The thickened pylorus is eased out and the duodenum is squeezed between the left index finger and thumb below the tumour to steady it and to prevent it sliding back into the abdomen. With a scalpel an incision half to three-quarters of an inch long is made along the pyloric tumour at its least vascular part, which is usually just above midway between the lesser and greater curvatures (Fig. 326A). The incision is deepened, using a smooth blunt (e.g. Watson-Cheyne) dissector, the fibres being divided with remarkable ease (Fig. 326B). Great care must be exercised when the incision approaches the duodenum, for its wall is very thin and the mucosa is so much closer to the serosa than that of the pyloric canal and may be perforated (Fig. 327). When the bulk of the muscle has been divided an artery forceps is introduced between the divided edges of the pyloric muscle and is slowly opened widely, gently tearing any remaining circular fibres so that on removal of the forceps the pyloric mucosa bulges into the incision It should be confirmed that air in the stomach can be easily squeezed into the duodenum, and that there is no leak through

the exposed mucosa. Any perforation in the mucosa may be closed with a mattress suture of fine catgut, and if there is any doubt the ends of the suture may be left long and a piece of omentum tied over the area. Occasionally a bleeding point requires ligature. The incision in the pyloric muscle is left widely open and the stomach is returned to the abdomen.

Occasionally the surgeon fails to find the anticipated pyloric thickening. In such a case the wound is enlarged slightly and search made for obstruction at other sites If none is discovered it may be presumed that the case is one of simple pylorospasm, which if severe enough to be mistaken for congenital pyloric stenosis will justify the surgeon in performing a pylorotomy much as it is done for the congenital stenosis.

The abdominal wall is closed in two layers, the posterior sheath and peritoneum and the anterior rectus sheath being sutured with fine catgut on an intestinal needle, and the skin with interrupted silk sutures.

Post-operative treatment.—After an operation on the stomach there is little or no gastric emptying for a period of between 8 and 24 hours.* Therefore, during this time only enough water or saline to keep the mouth moist is given, though half-ounce feeds of expressed breast milk may be given after 12 hours, or parenteral fluids may be continued. After 24 hours, two-hourly half-ounce feeds of saline and glucose are commenced, the feeds being increased by half an ounce in alternate feeds until three-hourly three-ounce feeds are taken. Half strength and then full strength breast or artificial milk gradually replace the saline. Recurrent vomiting is an indication to proceed more slowly. In the case of robust infants treated in an early stage and in suitable weather and when home circumstances are good some surgeons allow the child to be taken home within a day or two and to take breast feeds earlier. This diminishes the danger of contracting gastro-enteritis, a disaster more likely to occur in infants kept in hospital. There may be alarming pyrexia during the first few hours after operation but this almost invariably subsides spontaneously.

Results.—There are few surgical operations which give such satisfactory results, the majority of patients being restored to normal at once (Fig. 328). The late prognosis for a child who has survived a Rammstedt operation is excellent, and complications in adult life need not be feared. As a result of the operation the muscular thickening completely disappears.†

The mortality of the operation has steadily declined. In earlier days when surgery was delayed until prolonged medical treatment had been tried, the children were often close to death, and the *operation mortality* was often about 50 per cent Now when nearly all cases are operated on at an early stage, mortalities of under 2–3 per cent. are

* H K Faber and J H Davis, *J. Am Med Ass*, 1940, cxiv, 847
† M Wollstein, *Am J dis Child* 1922 xxv, 511

sometimes reported. Of T. H. Lamman and T. I. Mahoney's series of 425 treated at Boston in the years 1915–1931, all were treated by Rammstedt's method. In the first 125 the mortality was 10·4 per cent., in the second 150, 7 per cent., and in the last 150 cases only 2 per cent.* In breast fed infants with congenital pyloric stenosis, D. Levi† in 1941 reported 100 consecutive operations without mortality. His results were not so satisfactory in bottle-fed children, for of 46 cases there were six post-operative deaths, all due to gastro-enteritis



Fig. 328.—Congenital pyloric stenosis, one year after operation. Same case as Fig 324.

CONGENITAL DUODENAL OBSTRUCTION

There are two main types—the first results from a defect of canalization or atresia of the duodenum, the second cause is obstruction by peritoneal bands, usually associated with malrotation of the intestine.

Intrinsic or canalization defects (atresia).—These defects may result in narrowing, diaphragm formation, or obliteration of the lumen of a segment of the bowel which may be represented by a fibrous cord, or be absent altogether. The defect, which may be single or multiple, is sometimes above but more usually below the ampulla of Vater. Ladd found that five out of 52 atresias of the bowel were in the duodenum.‡

The symptoms, which date from birth, consist of vomiting of part or the whole of the feeds, the vomitus usually contains bile. The stool is small and dry and contains no milk curds. There may be intermittent epigastric distension.

Plain X-ray of the abdomen will show the dilated stomach and duodenum with no gas in the bowel below. A thin lipiodol or barium meal will confirm the diagnosis but it is to be given with caution because it may add to the obstruction, or may be inhaled. The barium should be aspirated after the radiological examination is completed.

* T H Lamman and T. I Mahoney, *Surg Gynec. & Obstet*, 1933, lvi, 205
† D Levi, *Brit. Med J*, 1941, June 28.
‡ Ladd and Gross, 1941, "Abdominal Surgery of Infancy and Childhood."

Treatment.—In view of the hopeless prognosis of the untreated case, surgery is amply justified.

The stomach should be lavaged pre-operatively and parenteral fluids may be required to correct dehydration. A three-inch right rectus splitting incision is made in the upper abdomen under general anæsthesia and can be enlarged as required. If the atresia is found to be above the ampulla of Vater a gastro-jejunostomy will be satisfactory. If below the ampulla, then a duodeno-jejunostomy is advisable. Antecolic anastomosis is usually necessary in view of the difficulty of the retrocolic operation.

The anastomosis may be extremely difficult because of the very small size of the empty jejunum. To overcome this the bowel may be distended with air by means of a syringe and fine needle, or a ureteric catheter may be threaded into the bowel to help define its lumen. It is sometimes possible to make a two-layer anastomosis of continuous fine catgut on an eyeless needle, but at times only one layer is feasible.

Post-operatively, gastric aspiration is continued until there is evidence that the stoma is functioning, and during this time parenteral fluids must be continued.

Congenital duodenal obstruction by extrinsic pressure.—When there is incomplete rotation of the cæcum, this part of the bowel lies just below the distal half of the stomach and peritoneal bands from it pass to the right postero-lateral wall of the abdomen. These bands or even the cæcum itself pass in front of the duodenum and may obstruct it, particularly if volvulus of the midgut occurs.

These cases may present as cases of duodenal obstruction, or a volvulus of the midgut may be the presenting lesion.

Clinical picture.—Symptoms usually arise shortly after birth but may appear later in childhood or at any time even up to adult life. The outstanding complaint is of attacks of vomiting, the vomitus containing food and bile. There is associated constipation and upper abdominal distension. If volvulus co-exists general abdominal distension and rapid deterioration of the child's condition may occur.

Plain X-ray examination of the abdomen may show the dilated stomach and duodenum, with only a small amount of gas in the bowel below. In older children a barium meal and enema show the duodenal obstruction and the malrotation of the colon.

Treatment.—Under general anæsthesia a right rectus incision is made. If dilated small bowel presents there is usually a volvulus present which first requires reduction. In order to do this the midgut is delivered out of the abdomen, and the bowel rotated back in the correct direction (the volvulus is usually clockwise).

Usually the cæcum presents and examination of the duodenum discloses its obstruction either by a band or by the cæcum itself. In either case the operation devised by Ladd* is performed (Fig. 329). The peritoneal band which fixes the cæcum to the right postero-lateral

* Ladd and Gross 1941, "Abdominal Surgery of Infancy and Childhood."

parietes is divided—after which the cæcum may be drawn to the left and the whole length of the duodenum is thus exposed. When this mobilization is completed, pressure on the duodenum is relieved. The cæcum is left lying to the left of the midline of the abdomen. Even in cases where small bowel obstruction is the urgent presenting

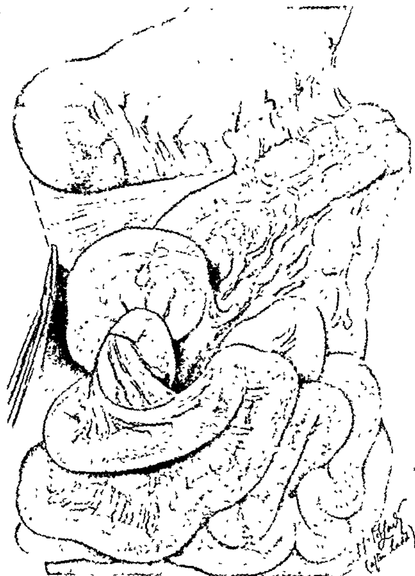


Fig. 329.—Congenital peritoneal band obstructing duodenum. The dotted line shows where the band should be divided.

symptom, it is wise to free the duodenum in this way after dealing with the volvulus.

Post-operative care.—Decompression *of the stomach* with a soft catheter will be required until the stomach contents become clear. Intravenous saline and glucose, and possibly blood will be required. Mouth feeding with diluted milk can usually be commenced by the third day.

Results.—Until fairly recent years congenital duodenal obstruction was a very fatal condition. Figures given by Ladd and Gross* represent the best now obtainable. Of 11 cases of atresia or stenosis of the duodenum there were 7 recoveries, and of 35 cases of intestinal and duodenal obstruction due to malrotation there were 27 recoveries

Ladd states that in cases of malrotation of the bowel, duodenal obstruction does not recur after the band passing in front of the duodenum has been adequately divided.

PEPTIC ULCERATION

In spite of a vast amount of clinical and experimental work the cause of peptic ulceration remains ill understood. There is an overwhelming amount of clinical and experimental evidence that gastric hyperacidity and hypersecretion is a very important factor. The parts played by infection, gastritis, vascular spasm or embolism, nervous tension and dietetic habits, are very debatable.

Indications for operation.—Hopes that some form of medical treatment might be discovered which would cure chronic peptic ulcer and prevent relapse have not yet been realized. Rest and dietetic therapy often lead to the healing of the ulcer, but in a very high proportion of cases relapses occur and can only be prevented by surgical treatment Many of the complications of peptic ulcer, perforation, hæmorrhage and stenosis, and occasionally the development of carcinoma, may demand surgical treatment.

Except when complicated by severe hæmorrhage or perforation, operation is not indicated for acute peptic ulcer or acute gastric erosions, because such lesions respond rapidly to medical treatment and often remain healed.

In the case of chronic peptic ulcer an adequate course of medical treatment should always be tried, particularly in the earlier stages. When patients consult a surgeon on account of an ulcer of many years' duration it frequently transpires that all they have had by way of treatment has been a few days' bed rest or a short ambulatory course of diet or alkali. Such perfunctory treatment usually causes a remission of symptoms but is insufficient to cure the ulcer, and should not be considered as " adequate medical treatment ".

Surgery is indicated in those chronic ulcers which fail to heal sometimes as a result of dense fibrosis of the base or fixation of the edge to the pancreas or liver, rarely as a result of malignant degeneration Failure of a gastric ulcer to heal should make the physician consider the possibility that the ulcer was in fact a malignant one from the start The duodenal bulb is practically never the site of primary malignant disease. Surgery is also indicated if the ulcer relapses after healing. Relapse of ulceration in a patient with a past history of gastric hæmorrhage or perforation is a strong indication for surgery.

* *Loc cit*

If there is suspicion that a gastric ulcer has undergone, or is likely to undergo malignant change, then early surgical treatment is imperative. Such suspicion may be aroused by failure of some usually successful palliative treatment, by the onset of new symptoms, by failure to heal as revealed by the gastroscopic or radiological findings, by involvement of the greater curve or prepyloric region, or by association of the ulcer with achlorhydria

Choice of operation.—There is considerable divergence of opinion on the procedure best suited to bring about a cure in the different types of peptic ulceration. Broadly speaking the operations are designed (1) to remove the ulcer, (2) to short-circuit the ulcer, (3) to lower the gastric acidity, or (4) combinations of these methods.

In the *first* group the outstanding method is the very successful partial gastrectomy. Various forms of local excision of the ulcer must be included such as wedge, sleeve and transgastric resection, Judd's operation, etc., but both in the stomach and duodenum these forms of local excision are so frequently followed by recurrent ulceration that it is doubtful whether they have any advantage over a prolonged course of medical treatment.

In the *second* group are gastro-gastrostomy, gastro-duodenostomy and gastro-enterostomy, and perhaps one should include some forms of pyloroplasty These operations give great relief from obstructive symptoms, and in such cases not infrequently lead to long-standing cure. In the absence of obstruction a lower incidence of relief is ... ve duodenal ulceration, there is a high incidence

In the *third* group are the operations of gastro-enterostomy, high partial gastrectomy and vagus nerve resection. The first of these lowers the acidity by introducing the alkaline duodenal contents into the stomach, the second by removal of a part of the acid secreting part of the stomach, and has also the advantage of removing the ulcer bearing area, while the last plan removes the vagus nerve control of the stomach. (*See* Physiological Considerations, p. 785.)

The *fourth* group includes those cases where the various operations are combined with vagotomy.

Duodenal Ulcer

This variety of chronic ulceration is the one in which high acidity is so marked a factor. Under certain rather rare circumstances, however, duodenal ulceration or scarring may be present in a patient with a low gastric acidity. There is a general trend towards a lowering of the gastric acidity with advancing years, or occasionally a lowering of the gastric acidity may occur as a result of an atrophic type of gastritis, and if either of these changes occur in a sufferer from duodenal ulcer it will usually be found that the ulcer has become inactive. Alternatively the ulcer may stenose and cause gastric stasis which in its turn may lead to gastritis and a lowering of the gastric acidity.

In the latter case a gastro-jejunostomy operation will relieve the symptoms and if the acidity remains low a permanently satisfactory result may ensue. The relief of the stasis, however, may also cure the gastritis and lead to re-elevation of the gastric acidity and the development of gastro-jejunal ulceration.

The incidence of gastro-jejunal ulceration after gastro-jejunostomy has been the subject of much difference of opinion. In the last few years many writers have suggested that the recurrence rate lies between 5 per cent. and 25 per cent.,*† whereas Sir James Walton, after a careful follow-up since 1919, found under 4 per cent. of recurrent ulcers in 896 cases.‡ In 1954 the writer in his Lettsomian Lectures described a ten year " follow-up " of a series of gastro-jejunostomies carried out for duodenal ulcer in 1943. Over 50 per cent. had developed stomal ulceration.§ Recurrent ulceration is often difficult to diagnose with certainty, clinically, and varying recurrence rates may result from different standards of diagnosis. For example, some might reasonably suggest that every patient with periodic post-cibal discomfort following gastro-jejunostomy has recurrent ulceration, whereas other clinicians would demand radiological, gastroscopic or operative proof. It is not unlikely, however, that just as with the passage of years the incidence of duodenal ulceration has risen, so the tendency to anastomotic ulceration may be rising.

Gastro-jejunostomy has the advantage of having a lower operative mortality than gastrectomy in average hands, and so, apart from the risk of anastomotic ulceration, would be preferable. Endeavours have been made to decide pre-operatively which cases would be likely to develop recurrent ulceration, as in such cases high partial gastrectomy would be the operation of choice. Young patients with high acidity, rapidly emptying stomachs and gastroscopic signs of hypertrophic or thick mucosa appear to be the most susceptible to anastomotic ulcer, so that for such cases gastro-jejunostomy is inadvisable.

Modified gastrectomy for duodenal ulcer.—In the writer's practice the incidence of gastro-jejunal ulceration after gastrectomy for duodenal ulceration was two anastomotic ulcers in 91 gastrectomies examined five years after operation.‖ It has been suggested that in order to make the operation easier and safer, it may be wise to leave the pyloric antrum unresected, that is to transect the stomach in the prepyloric region, close the antrum and then remove the major part of the body of the stomach. This operation was soon followed by a very high incidence of anastomotic ulceration, in excess of 20 per cent. In explanation it is suggested that Edkins "gastrin", the hormone secreted by the antral mucosa, remains active and continues to stimulate the fundic glands to secrete acid juice. A further modification was tried

* F. Lahey, *New Engl J Med*, 1946, ccxxxiv, 809
† W A Cooper, *Surgery*, 1948, xxiii, 425
‡ Sir J. Walton, " Modern Operative Surg ," 1944, Cassell, London, p. 683
§ N C Tanner, *Postgrad Med J*, 1954, xxx, 451
‖ N. C. Tanner, *West London Med. J*, 1947, liii, 1

out for cases in which it was considered that removal of the duodenal ulcer and antrum might be fraught with grave danger. This was to transect the stomach in the prepyloric region, carefully remove or "core out" the mucous membrane of the pyloric antrum and canal and then close the seromuscular coats of the antrum followed by a high resection of the stomach. This proved a valuable though more tedious procedure. Simple duodenal transection and closure is to be preferred if it is possible without undue risk.

Vagotomy.—Vagus nerve resection must remain under trial for several more years. There is no doubt that in a high proportion of cases it leads to a marked diminution of acid secretion, but how permanent this effect will be is not yet known, though it has been observed that there is in some cases a tendency for the acid secretion level to rise towards the end of the first year. In the majority of those cases in which the volume and acidity of the secretion was depressed by the operation, it remains depressed four to five years after operation. Together with the diminution in acidity there is also considerable atony and diminution of peristaltic activity in the stomach. This leads to delayed emptying even in the absence of any obstruction of the duodenum, and much more delay in the presence of scar contraction of the duodenum. The advantages of vagotomy are that it is an operation of less severity than gastrectomy, and the so-called "dumping syndrome" or "post-cibal effects" do not follow. On the other hand, after vagotomy post-operative "side effects" may occur, which are largely due to the combination of gastric stasis with hypochlorhydria. The main troubles are foul eructations, diarrhœa, and symptoms suggestive of mild hypoglycæmic attacks. A three-year follow-up shows that over 80 per cent. become free of ulcer symptoms, though some of these may require further surgery to correct gastric retention. Nearly all surgeons now combine vagotomy with gastro-enterotomy or pyloroplasty, or even gastrectomy, in order to prevent or diminish the stasis symptoms.

The choice of operation for any particular case of duodenal ulcer is still a matter of opinion and personal experience. No doubt the question will be influenced by the future histories of patients already subjected to vagotomy which are not yet available.

The writer's routine is as follows:—

Medical treatment is advised for all early cases, particularly if duodenal deformity has not occurred. Adequate medical management includes a course of bed rest, preferably lasting for four or more weeks and until X-ray shows disappearance of the ulcer niche and spasm. If the ulcer relapses after more than one such course then surgery is indicated Relapse of symptoms after previous medical treatment for hæmatemesis, or after treatment of a perforated ulcer in a patient with a history of chronic ulceration, is a definite indication for surgical intervention.

Pyloric stenosis in which the narrowing is considered to be due to

fibrous scarring of the duodenum is an absolute indication for surgery. In cases where the gastric retention is due to spasm of the duodenum, or to œdema in the ulcer region, great benefit may result from medical treatment. Nevertheless, the majority of duodenal ulcers which have advanced to the stage of producing stenotic symptoms will relapse even after successful medical treatment so that surgery is recommended to practically all such patients as soon as they have been made fit for it.

Although duodenal ulceration is usually associated with a high gastric acidity, under some circumstances the acidity may have become normal or even low, but symptoms may persist as a result of severe scarring, narrowing and deformity of the duodenum. In such cases the operation of *gastro-jejunostomy* may be carried out, but such cases are not frequent, and in all there is some risk of subsequent anastomotic ulceration. The surgeon may be influenced by other factors, when advanced age or intercurrent disease in the patient, or even lack of experience on the part of the surgeon, may at times make the simpler operation of gastro-jejunostomy advisable. Needless to say, most patients will prefer to risk developing anastomotic ulceration rather than run a grave risk of death.

For the majority of the cases the choice of operation lies between gastrectomy and vagus nerve resection, the latter being combined with gastro-jejunostomy or pyloroplasty.

Partial gastrectomy is a well-tried procedure. The mortality nowadays is low, the writer having a mortality of 1·3 per cent. in 1,275 interval gastrectomies carried out for duodenal, gastric or anastomotic ulceration between 1941 and 1953. This operation is usually followed by complete relief of ulcer symptoms and satisfaction in about 90–95 per cent. of cases, though recurrent ulceration may occur in 2–3 per cent. and postcibal symptoms of sweating, faintness, etc., in about 7 per cent. of the patients.

Vagus nerve resection also carries a very low mortality, usually under 1 per cent.

The writer's practice is to combine vagotomy with a drainage operation, usually pyloroplasty, and to reserve it for young sufferers in whom the weight loss occasionally associated with gastrectomy may prejudice growth. It is also used in cases with short histories and for subjects with a very high acidity and rapidly emptying stomach—that is, the type which is most prone to recurrent ulceration after gastrectomy.

Gastric Ulcer

In gastric ulcer the acidity is usually near normal, but it may be low and achlorhydria is occasionally present.

Gastro-jejunostomy results in healing of the ulcer in some cases, and the nearer the ulcer is to the pylorus the more likely is it to be successful. The number of cases in which relapse occurs is too high to warrant this operation as a routine procedure, and in addition it does not guard against malignant change in the remaining ulcer.

Partial gastrectomy has proved to be the most generally satisfactory operation for gastric ulcer. To a surgeon who has mastered the operative technique it carries little more risk or difficulty in performance than wedge or sleeve resection, but it has the great advantage that recurrent gastric or anastomotic ulceration is almost unknown as a sequel In the writer's series of over 700 such resections for gastric ulcer (uncomplicated by duodenal ulceration), only one such recurrence has been encountered. The resection may be completed by anastomosis of the gastric remnant either to the duodenum, the Billroth I type, or to the jejunum, the Polya type.

In cases in which the ulcer is close to the œsophagus, transverse transection of the stomach above the ulcer in the usual way would involve total gastrectomy, an operation carrying a much higher mortality than partial gastrectomy, and of a severity which is not justifiable for the average case of simple gastric ulcer. The most satisfactory way of dealing with this type of case is to use Pauchet's modification of partial gastrectomy, which is an extremely satisfactory procedure. (*See* High Gastric Ulcer, p 813.)

Some surgeons have reported satisfactory results in high ulcer cases following partial gastrectomy below the ulcer, leaving the latter *in situ*. There is the obvious risk that the ulcer may not heal or may develop some complication. The writer has little personal experience of the procedure, but, nevertheless, the good results reported appear to make it justifiable, particularly when the surgeon doubts his ability to perform a Pauchet operation satisfactorily, or where there is extensive involvement of the œsophagus, short œsophagus or obesity combined with a deep abdominal cavity.

The writer's custom, therefore, in the surgical treatment of gastric ulcer is to perform partial gastrectomy, modified when required by adopting Pauchet's procedure.

Preparation for Operation on the Stomach or Duodenum

Many of the patients who come for operation will have had a course of medical treatment with bed rest and a good dietary, and will be in good condition for surgical treatment. For those with recent active ulceration or who have been at work until the time of admission careful pre-operative preparation is necessary. It is advisable to have the patient in hospital for at least three full days before operation and a week or more is required in some cases. Daily gentle exercise and particularly respiratory and leg exercises are helpful.

The teeth should be cleaned and fillings and extractions carried out as necessary in the less urgent cases Smoking appears to increase the likelihood of post-operative pulmonary complications and the patient should abstain from tobacco for a week prior to operation.

Varying degrees of starvation, fluid, salt or vitamin deficiency, or anæmia, may be present and must be corrected. In severe cases it may be necessary to give glucose and saline, and sometimes amino acids or plasma by the intravenous route. Rectal saline may also

be well absorbed. If the deficiency is due to a fear of eating because of pain, or due to self-inflicted incorrect dieting, then bed rest, alkalis and ample diet will remedy the condition, though on rare occasions feeding by means of an indwelling gastric tube may be advisable. If starvation is due to pyloric stenosis then gastric lavage with saline once or twice a day will usually produce a dramatic improvement within a few days. Ample protein in the form of milk and eggs should be the mainstay of the diet and extra vitamins, particularly C and B complex, are advisable. Anæmia may be corrected by the administration of ferrous iron by mouth, or by blood transfusion. Operation should not be considered until the hæmoglobin level reaches at least 70 per cent.

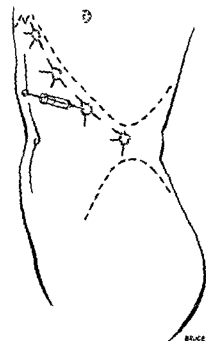


Fig. 330.—Sites of injection for producing local anæsthesia of upper abdominal wall.

Normal meals are given the day prior to operation, and a light breakfast of toast and tea may be given on the day of operation provided that it is taken at least five hours previously. If there is pyloric stenosis then the stomach is washed out with saline at least two hours before transfer to the theatre. It is helpful to introduce and leave a soft œsophageal catheter in the stomach for deflation of the viscus during and just after operation.

Prophylactic chemotherapy.—The incidence of pulmonary complications after operation appears to be reduced by the administration of sulphonamide or penicillin.* One of these drugs may be administered prophylactically in frail or bronchitic subjects. In the case of the sulphonamides the first dose may be given by mouth six hours before operation, and in the case of penicillin the first injection is given immediately prior to operation. The object is to try to obtain an adequate blood concentration of the drug during and for the first four days following operation.

Choice of anæsthetic.—Many different methods of anæsthesia may be used and by consultation and co-operation with the anæsthetist good results may be obtained from any of them. For the majority of patients some general anæsthesia is preferred, and may be combined with local anæsthesia, or a relaxant drug. Spinal anæsthesia gives excellent relaxation and is still the method of choice in some clinics. It is possible to perform the operation using only local anæsthesia, particularly now that safe local anæsthetic agents which last three to five hours are available. The one favoured by the writer is amethocaine

* N C Tanner *Brit Med. J*, 1943, i 563

hydrochloride 1 : 2,000 with adrenaline 1 : 400,000 in normal saline solution in doses of up to 400 c.c. An abdominal field block, infiltrating the muscle layers just medial to the costal margins from xiphisternum almost to the iliac crests, is preferred to introducing the solution into the rectus sheath (Fig. 330). Splanchnic anæsthesia may be obtained with the same solution either by the posterior (Kappis) or anterior (Braun) route, or by infiltration round the main gastric vessels. Local anæsthesia is a valuable method in frail or elderly patients, or patients with pulmonary disease. It has been the writer's experience that the

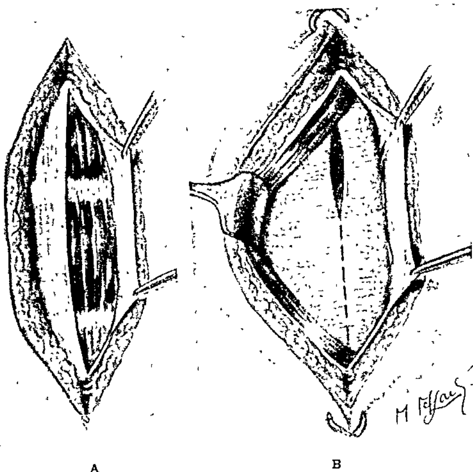


Fig. 331.—A, Right paramedian incision. The inner flap of the aponeurosis is dissected off the rectus muscle. B, The posterior aponeurosis and peritoneum incised after retracting the rectus muscle to the right.

more local anæsthesia is indicated—that is the more ill, frail or aged the patient—the better it is tolerated

Operative technique. The incision.—Many incisions have been advocated, the most generally useful being an upper right paramedian or midline or a high transverse one. There is some tendency for midline incisions to weaken and bulge some months after operation, so that if used they should be repaired with continuous or interrupted sutures of silk, wire or nylon. Transverse extensions from one or

other side of a paramedian incision are sometimes helpful (*see* Duodenal Ulcer). The abdomino-thoracic incision is described under operations for gastric carcinoma.

The paramedian approach is the one most used. A vertical incision is made an inch to the right of the midline from the xiphisternum level to the umbilicus. All bleeding is controlled and skin towels are fixed to the subcutaneous fat. The anterior aponeurosis is divided in the line of the skin incision and the internal flap dissected off the rectus muscle (Fig. 331A). The rectus is retracted outwards, and the posterior aponeurosis divided in the line of the skin incision (Fig. 331B), so that when finally sutured this incision is completely covered by the rectus muscle. After opening the peritoneal cavity it is often found that the falciform ligament obstructs the view of the upper stomach, in which event it may be divided and ligatured. If the division is made near the liver the ligatured ends will come to lie out of harm's way on closure of the abdomen between liver and parietes rather than in contact with the bowel. For very high ulcers or for exposure of the abdominal œsophagus, the device recommended by Professor Grey Turner of dividing the left coronary ligament and turning the left lobe of the liver to the right will be found extremely useful.

An exception to the rectus displacing method may be made when re-opening an old incision. In such cases the rectus sheath is adherent to the muscle and the dissection may be tedious and cause more bleeding than is usual. It is simpler in such cases to cut directly through the scar, the rectus muscle and posterior aponeurosis. This may later be repaired in layers as described, or closed with interrupted sutures of silk or wire. I would deprecate the practice of using a new incision in each of several operations on the stomach, for multiple epigastric incisions are unsightly and depressing for the patient; they are prone to bulge and each fresh peritoneal opening widens the area of adhesions between the viscera and anterior parietes

As soon as the abdomen is opened a general investigation is carried out. It is advisable first to examine the viscera thought to be healthy, for as soon as the suspected lesion is found the surgeon's attention may become so concentrated upon it that he may forget the rest of the abdomen. The hand should be inserted into the pelvis and its contents systematically palpated, then the organs in the right and left abdomen, and retro-peritoneal organs such as the pancreas and kidneys are similarly examined. The colon and gall bladder are felt with particular care in view of the frequency with which they are involved in disease. Finally, the stomach and duodenum are felt, and when the region of the cardiac orifice is examined, the state of the œsophageal hiatus is also investigated. If there is any doubt about an organ then it should if possible be brought to the wound for inspection.

Closure of incision.—When the operation is completed the posterior aponeurosis and peritoneum are held up with Spencer Wells forceps and sutured as one structure with continuous catgut, fine linen or silk.

The anterior rectus sheath is sutured with a fresh running suture of the same material and the skin with interrupted sutures of fine silk. Many surgeons use a few through and through sutures of silk-worm gut or silk in addition, and this is certainly wise in anæmic patients or if nutrition is poor.

Gastro-Jejunostomy

Identification of the ulcer.—In a supposed case of duodenal ulcer the lesion must be identified beyond doubt by the presence of scarring and the characteristic speckling of the peritoneum over it. The peritoneum adjacent to the ulcer is fixed to the underlying muscle coat and cannot be moved over it. There is some local induration and the crater may be felt. In the case of posterior wall ulcers the posterior surface of the duodenum may be examined through an opening into the lesser sac made through the gastro-colic or gastro-hepatic omentum. In penetrating ulcers the duodenum will be

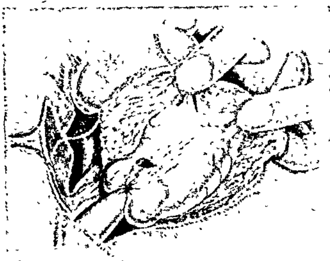


Fig. 332.—Scarring of the duodenum from old ulcerations with formation of false diverticulæ.

adherent to the pancreas and a firm induration of the pancreas adj[illegible] to the crater will be felt. Care should be taken not to miss the pres[illegible] an ulcer at the junction of the first and second parts of the duod[illegible] or even in the second part. There may be a shortening and [illegible] of the duodenum between the pylorus and ulcer producing the s[illegible] "prestenotic diverticulum" (Fig. 332). It must be empha[illegible] *if the duodenum is not inspected* as well as palpated the pres[illegible] ulcer or ulcer scar may be missed

Technique of the operation.—Whenever possible a [illegible] anastomosis should be made. This gives more satisfactor[illegible] is less likely to be followed by post-operative gastric rete[illegible] anterior one. The great omentum, the transverse c[illegible] stomach are drawn out of the wound and turned upwards, [illegible]

the under surface of the mesocolon. This is opened by a vertical incision in a bloodless space, usually between the left and middle colic arteries, the so-called space of Riolan. The opening is enlarged until it is three to four inches in length, and the posterior wall of the stomach is grasped at the lesser curve with the right hand and at the greater curve with the left hand (Fig. 331). The portion of the



Fig. 333.—Posterior gastro-jejunostomy. The transverse colon has been turned up, the mesocolon incised and a portion of the stomach withdrawn.

stomach so held is withdrawn and rotated counter-clockwise. An assistant applies a non-crushing clamp, the handle being towards the patient's left. By this means the stoma will be placed vertically on the posterior wall of the stomach. If preferred it may be made to incline to the right or left with no impairment of the immediate or late results, but the vertical opening usually lies more easily. The portion of the stomach selected for anastomosis should be as far

towards the pylorus as is technically convenient, because this part of the stomach is alkali secreting.*

It is a good plan to suture the cut edges of the mesocolic opening to the stomach around the clamps at this stage. This is done with seven or eight interrupted fine non-absorbable sutures, and is intended to prevent later herniation of jejunum into the lesser sac (Fig. 334).

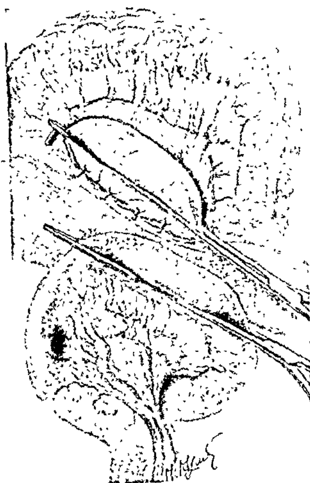


Fig. 334.—Gastro-jejunostomy. With fine interrupted stitches the cut edge of the mesocolon is sutured to the stomach beyond the clamp.

The upper end of the jejunum is then identified beyond all question and picked up, and the duodeno-jejunal junction clearly seen and examined for abnormalities. The contents of the first eight inches are " milked " away, and a non-crushing clamp is applied with the handles towards the patient's left, and about three to four inches from the duodeno-jejunal junction, so as to engage a loop of intestine of a similar length to the part of the stomach already clamped. At one time it was advocated that the clamps should be applied as close to the duodeno-jejunal junction as possible—the no-loop operation.

* N. C. Tanner, *Bristol Med. Chi. J.*, 1946, lxiii, 16.

The presence of tension is contrary to all surgical principles and therefore a loop of sufficient length to avoid tension, about three to four inches, should be left on the proximal side. The assistant holding the handles of the clamps approximates the two and if locking twin clamps are used they are fixed in this position with the loop and screw The proximal part of the jejunum should be apposed to the lesser curve of the stomach. The omentum, transverse colon, and the rest of the stomach are now replaced in the abdominal cavity through the upper part of the incision, and the clamps and their contents are shut off from the peritoneal cavity by placing two gauze packs under and around them, or a special red "anti-soiling" towel used by the writer which has a pocket for the clamp handles may be used. A suture of No. 00 catgut mounted on an eyeless needle is passed through the seromuscular coats of both viscera near the handles of the clamps and tied. The short end is secured with forceps, and the whole length of the approximated viscera is joined by a continuous seromuscular suture (Lembert), with a lock stitch placed at the end near the clamp points.

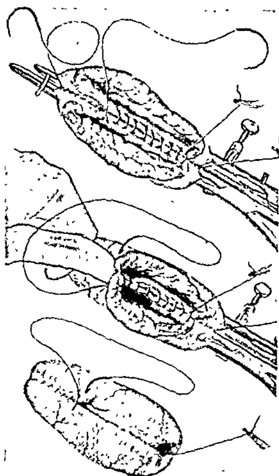


Fig. 335.—Posterior gastro-jejunostomy. Top, the posterior seromuscular suture is completed and the "all coats" suture commenced. At middle, the anterior "all coats" suture is nearly complete. Bottom, the clamps have been removed and the anterior seromuscular suture is being introduced.

The stomach is now opened for a distance of 4–6 cm. by an incision parallel with the suture line and about 0·5 cm. from it. This should be done in two stages, first the seromuscular and then the mucous coats being divided, any fluid content of the bowel being immediately removed. The jejunum is opened by a similar incision. The adjacent (posterior) edges of the openings in the stomach and jejunum are then united by a continuous through and through catgut suture (Fig. 335). This suture, too, may be conveniently commenced at the extremity of the incision near the clamp handles and after knotting the short end is held in a forceps. The writer finds it convenient to use a long artery forceps for the short end of catgut in the seromuscular layer ("long for Lembert") and a short forceps for the "all the

coats" layer to prevent confusion. This latter layer must be placed with care to ensure that all the coats are taken with each bite, and to ensure hæmostasis the stitches should be about an eighth of an inch apart and the catgut kept fairly taut. The wider apart the stitches, the more tissue must be taken with each bite to ensure hæmostasis. When the other extremity of the posterior cut edges is reached, then the corner must be turned and the anterior edges united, until the suture meets its beginning and the two ends are securely tied (Fig. 335). The "all the coats" stitching is best done by a simple continuous stitch, and on the anterior layer the left thumb may be used to invert the mucosa, though a little protruding mucosa is of but slight consequence. The Connell stitch may be used for this layer, though it is probably not so hæmostatic as the simple continuous stitch. The main thing is that the surgeon must either use a suture which he knows to be efficient and hæmostatic, or if he has any doubts on the matter, then before starting the "all the coats" layers the clamps must be temporarily loosened and each bleeding-point caught and tied.

The clamps, red towel and any instruments used while the bowel cavity was open are considered soiled and are now discarded, and the surgeon and assistant wash or change their gloves The seromuscular suturing is then resumed (Fig. 335) and the anterior "all the coats" suture line buried by the continuous Lembert stitch which is finished off by knotting with the original end.

Some surgeons advocate a three-layer suture, stitching the cut seromuscular edge and the mucosal edges separately. As the major vessels lie between these two layers it is not so hæmostatic as a single continuous "all the coats" stitch.

The anastomosis is inspected and an extra stitch placed wherever the suture line appears insecure. Any large vessels entering the suture line may be underrun with interrupted stitches. These few extra stitches are usually unnecessary, but as Moynihan said, they give the surgeon a feeling of security—he called them "hypnotic stitches", as he slept better knowing they were there

The viscera are now returned to the abdomen and the abdominal wall closed.

On occasions variants of this form of gastro-jejunostomy may be found preferable. If the mesocolon is short or absent, is excessively fatty, unusually vascular, or is scarred, an anterior anastomosis may be performed A loop of jejunum is brought loosely round the left half of the transverse colon and clamped. It must not constrict the bowel, but it must not hang as a free loop. The proximal portion will usually be six to eight inches in length. The anastomosis may lie parallel with the greater curvature with its afferent loop towards the cardiac end (Fig. 336A, B), or may be vertical with the afferent loop towards the lesser curve, so that gravity will aid in emptying the stomach. If the latter direction is used the afferent loop should be stitched against the stomach in a gentle curve to prevent kinking.

If the gastro-jejunostomy is a palliative procedure for carcinoma

of the pyloric end of the stomach then it is advisable to make the anastomosis to the part which is likely to be last involved in growth This usually means an *anastomosis against the greater curvature* high up, after dissecting the gastro-colic omentum free from the stomach (Fig. 336c) and again the efferent loop should be dependent.

Two variants of gastro-jejunostomy should be avoided in operating for peptic ulcer. One is the Roux operation (Fig. 336E) where an end-in-side jejuno-gastrostomy is made and the other is jejuno-jejunostomy (short-circuiting the afferent and efferent loops) following gastro-jejunostomy (Fig. 336D). In both of these variations the duodenal juices are diverted from the part of the jejunum anastomosed to the stomach, with the result that the passage of undiluted gastric

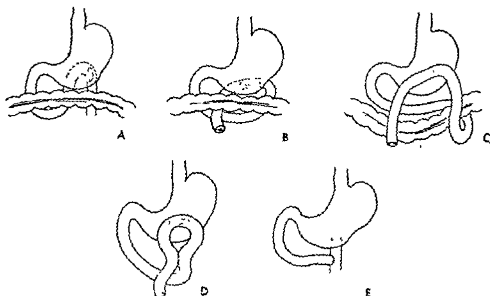


Fig. 336.—Gastro-jejunostomy. A and B, Posterior retro-colic. C, Ante-colic. D, With entero-anastomosis. E, Roux type. A, B and C are satisfactory; D and E are unsatisfactory.

juice over this part of the jejunum leads to anastomotic ulceration in a high percentage of the cases.

Partial gastrectomy.—Many methods of partial gastrectomy have been employed; they differ mainly in the method by which the subsequent gastro-duodenal or gastro-jejunal anastomosis is carried out. The two methods most commonly employed at the present time are· (*a*) some form of the Billroth I (Péan) operation, where the stomach is united direct to the open end of the duodenum (Fig. 337); and (*b*) some variety of the Polya (Reichel) operation, where the stomach is implanted into the side of the jejunum (Fig. 338). It is the writer's practice to use the Polya method in most cases of duodenal ulceration or lower gastric carcinoma, because in the former the duodenum is inflamed and deformed and one cannot be sure that superficial scarring or ulceration may not be present in the part retained and used for anastomosis in the Billroth I, and in the latter

a radical extirpation of glands and adjacent vessels makes it wise to remove much of the first part of the duodenum. For gastric ulcer the Billroth I type of operation is quite satisfactory. It is usually easy to perform and troubles caused by obstruction or kinking of the afferent or efferent loops such as may occur in the Polya procedure are avoided. The final anatomical result approximates closely to the normal. Other indications for the Billroth I operation are extensive adhesions between the colon or great omentum and the parietes, or incomplete rotation of the colon (in which there may be no duodeno-jejunal flexure).

Technique. The Billroth I operation.—The great omentum and transverse colon are drawn out of the incision. The greater curve of

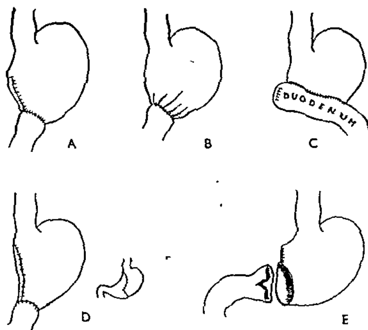


Fig. 337.—Partial gastrectomy with direct gastro-duodenal anastomosis in various forms. E illustrates Rutherford Morison's method of enlarging the duodenum.

the stomach is first freed from the transverse colon and the great omentum. An opening is made through the gastro-colic omentum well to the left—in the region of the left gastro-epiploic artery, and a finger placed in the lesser sac displays the artery and vein, which are doubly clamped, ligatured and divided. Similarly all the descending epiploic branches are lifted up just below the gastro-epiploic arch, one or two at a time and divided between ligatures or clamps. Towards the pyloric part of the stomach adhesions between the mesocolon and posterior wall of stomach will be found which should be gently separated before dividing the epiploic vessels Care is needed here, for the middle colic and right gastro-epiploic arteries will be found in close proximity. The right gastro-epiploic artery and vein, usually accompanied by lymph nodes, will be found coming forwards from behind the duodenum and are carefully isolated, clamped, divided and tied.

Some surgeons prefer to preserve the gastro-epipoic vascular arch, in which case the gastric branches running up from it, rather than the epiploic branches, are divided. A few fine vessels entering the posterior duodenal wall may be divided in order to assist mobilization. A finger is now passed upwards behind the stomach and is easily thrust through the tenuous lesser omentum. The portion of this structure, lying between the finger and the duodenum and containing the pyloric (right gastric) artery, is tied and divided. By this means the structures in the right edge of the gastro-hepatic omentum are kept to the right out of harm's way (Fig. 339). The duodenum is thus freed above and below and may be divided between two fine anastomosis clamps (e.g. Stevenson's). Both ends are covered with gauze to prevent soiling.

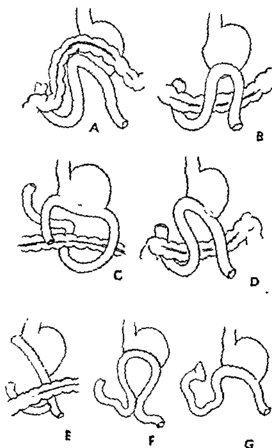


Fig. 338.—Partial gastrectomy with gastro-jejunal anastomosis. A, B, C and D are satisfactory; E, F and G are unsatisfactory.

The stomach is drawn down and turned upwards over the left costal margin, displaying the left gastric vein and artery. These are defined and ligatured, together with all the fatty and glandular tissue high on the lesser curve of the stomach (Fig. 339). The pedicle is divided between clamps and a second ligature is applied. The stomach is thereby mobilized. Further vessels, the vasa brevia, are ligatured and divided on the greater curve side until the desired level of gastric transection is reached. The stomach is lifted up and clamped proximal to the proposed line of section. After suitable gauze protection has been arranged it is divided with a knife or scissors and the part to be removed is taken away. The opening is approximated to the duodenum which may also be held in a twin non-crushing clamp. The clamps are now surrounded with protective towels The upper lesser curve half of the stomach lumen is closed and the lower half anastomosed end-to-end to the duodenum One of the numerous methods of effecting this is as follows. A seromuscular suture is passed to unite the lower border of the duodenum to the greater curve of the stomach, tied and the short end clamped. This suture is carried on as a continuous stitch to the upper border of the duodenum, and so ends about the middle of the posterior wall of the stomach.

The part of the gastric diameter above this point is clamped with a crushing clamp and the stomach is transected and removed just beyond the crushing clamp so that about half the diameter is now held in the clamp and the lower half opposite the duodenum is open (Fig. 340). The part held by the crushing clamp is closed with a running or "sewing machine" stitch and the crushing clamp is removed. The remaining open end of the stomach is united by an "all the coats"

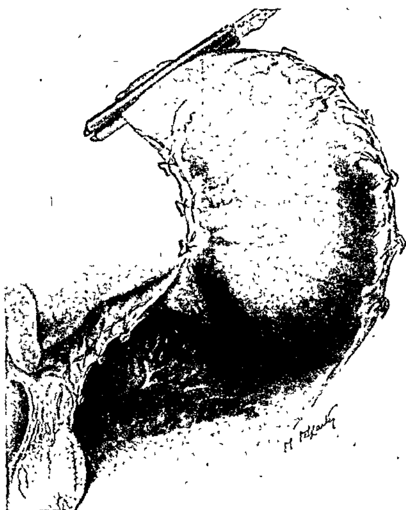


Fig. 339.—Ligature and division of the coronary artery close to its origin from the cœliac axis. There should be a much freer removal of the small omentum.

stitch to the open end of duodenum as already described under gastro-jejunostomy (Fig. 341). The duodenum must be made freely mobile, and by freeing any anterior adhesions to its first part, and if necessary making a vertical incision on the peritoneum lateral to the second part and then drawing and gently pushing the duodenum medially (Kocher's mobilization). The open part of the suturing being completed the protective towels and clamps may be removed. The

upper closed half of the stomach, especially the upper corner, is now deeply buried, with a seromuscular stitch which ends at the superior part of the gastro-duodenal anastomosis. The seromuscular stitch which united posterior surfaces of the duodenum and stomach is now continued round to the anterior surface, burying the "all the coats" gastro-duodenal layer (Fig. 342), until its commencement is met, to which it is tied. An extra suture may be applied between the upper part of

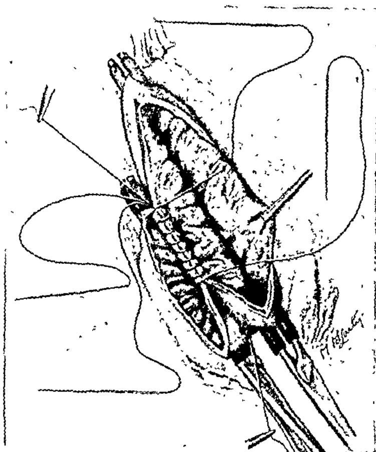


Fig. 340.—Billroth I partial gastrectomy.

The requisite portion of stomach has been removed, the posterior sero-muscular suture completed, and the hæmostatic "all coats" suture commenced. The upper half of the divided stomach may more conveniently be held in a Payr clamp.

the duodenum, and the adjacent stomach to reinforce the so-called "danger angle".

This operation may be carried out without clamps provided the stomach is empty and controlled by a careful assistant. In such a case a suction apparatus must be used to keep the field dry, and all bleeding points should be ligatured. If the duodenum is narrow its lumen may be enlarged as shown in Fig. 337E, as suggested by Rutherford Morison many years ago.

High gastric ulcer.—For ulcers situated high up on the lesser curvature the writer finds a variation of Pauchet's operation very useful (Figs. 343 and 344). The preliminary steps are the same as just described, but after the stomach has been well mobilized, particularly along its greater curvature, and the duodenum mobilized and divided, the stomach is shut off from the peritoneal cavity by packs, and is then clamped with two Payr clamps at a convenient point for the subsequent

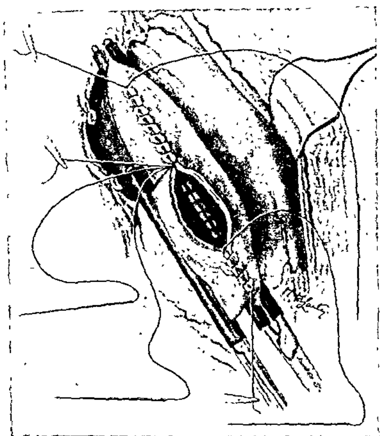


Fig. 341.—Billroth I partial gastrectomy.
The upper half of the divided stomach is closed and the "all coats" suture is being carried on to unite with duodenum.

anastomosis, which will be below the level of the ulcer, and extending half-way across the diameter of the stomach from its greater curvature side. The stomach is divided between them. Two Parker-Kerr or similar curved crushing clamps are now placed from the tips of the Payr clamp to arch above the ulcer to the lesser curve of the stomach (Fig. 345), and the stomach is divided between them and the distal part containing the ulcer removed. The part of the stomach held in the Parker-Kerr clamp is then closed in two layers and the greater curve half, held in the Payr clamp is anastomosed end-to-end to the duodenum. At times the ulcer is too high for Parker-Kerr clamps

to be placed above it, in which case the excision of the tongue-shaped piece of the lesser curve containing the ulcer is made with scissors segment by segment, closing the cut edges as the incision is carried



Fig. 342.—Billroth I partial gastrectomy. Clamps removed and anterior seromuscular suture being completed. One or two additional sutures are to be inserted at the dangerous angle.

farther up towards the cardia If the incision encroaches on the œsophagus, care is necessary to see that the latter is not unduly narrowed by suturing. In these circumstances it is helpful to pass a large bore stomach tube to act as a guide during the repair.

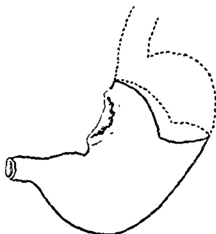


Fig. 343.—Pauchet form of resection.

The Billroth II operation.—In the Billroth II gastrectomy the duodenal and gastric ends are both closed and a gastro-enterostomy made between a loop of jejunum and the part of the stomach remaining, the anastomosis being either ante- or retro-colic (Fig. 338) This operation has little to recommend it and is hardly ever used nowadays.

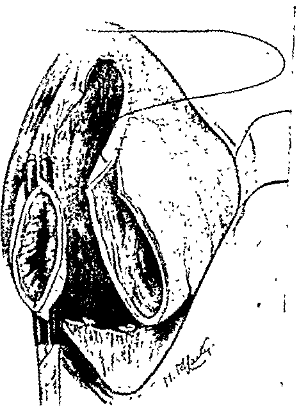


Fig. 344.—Pauchet's *operation. Suture of the* lesser curvature. When this is finished the operation may be completed by either the Billroth I or the Polya methods.



Fig. 345.—After clamping and dividing the lower half of the stomach, two curved crushing clamps (Parker-Kerr) are placed to arch above the ulcer.

to be placed above it, in which case the excision of the tongue-shaped piece of the lesser curve containing the ulcer is made with scissors segment by segment, closing the cut edges as the incision is carried



Fig. 342.—Billroth I partial gastrectomy. Clamps removed and anterior seromuscular suture being completed. One or two additional sutures are to be inserted at the dangerous angle.

farther up towards the cardia. If the incision encroaches on the œsophagus, care is necessary to see that the latter is not unduly narrowed by suturing. In these circumstances it is helpful to pass a large bore stomach tube to act as a guide during the repair

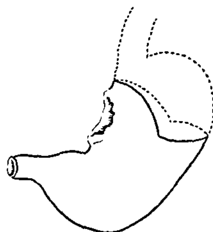


Fig. 343.—Pauchet form of resection.

The Billroth II operation.—In the Billroth II gastrectomy the duodenal and gastric ends are both closed and a gastro-enterostomy made between a loop of jejunum and the part of the stomach remaining, the anastomosis being either ante- or retro-colic (Fig. 338). This operation has little to recommend it and is hardly ever used nowadays

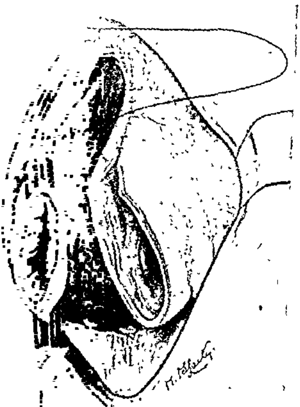


Fig. 344.—Pauchet's operation. Suture of the lesser curvature. When this is finished the operation may be completed by either the Billroth I or the Polya methods.

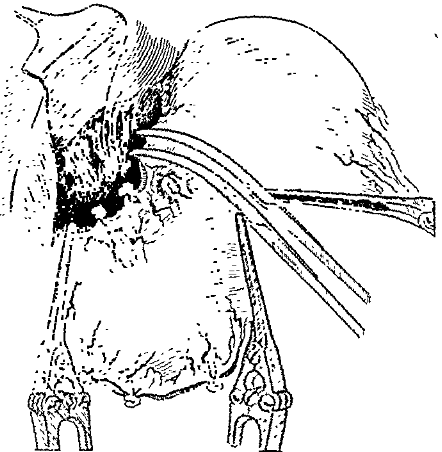


Fig. 345.—After clamping and dividing the lower half of the stomach, two curved crushing clamps (Parker-Kerr) are placed to arch above the ulcer.

to be placed above it, in which case the excision of the tongue-shaped piece of the lesser curve containing the ulcer is made with scissors segment by segment, closing the cut edges as the incision is carried



Fig. 342.—Billroth I partial gastrectomy.
Clamps removed and anterior seromuscular suture being completed. One or two additional sutures are to be inserted at the dangerous angle.

farther up towards the cardia. If the incision encroaches on the œsophagus, care is necessary to see that the latter is not unduly narrowed by suturing. In these circumstances it is helpful to pass a large bore stomach tube to act as a guide during the repair.

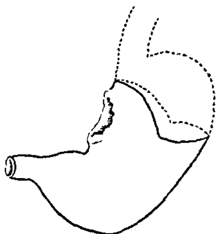


Fig. 343.—Pauchet form of resection.

The Billroth II operation.—In the *Billroth II* gastrectomy the duodenal and gastric ends are both closed and a gastro-enterostomy made between a loop of jejunum and the part of the stomach remaining, the anastomosis being either ante- or retro-colic (Fig. 338) This operation has little to recommend it and is hardly ever used nowadays.

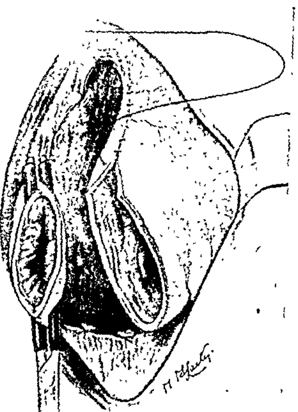


Fig. 344.—Pauchet's operation. Suture of the lesser curvature. When this is finished the operation may be completed by either the Billroth I or the Polya methods.

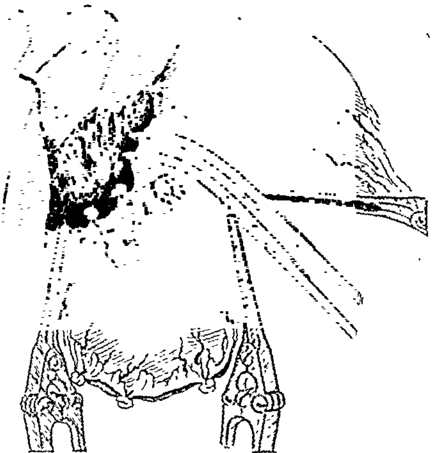


Fig. 345.—After clamping and dividing the lower half of the stomach, two curved crushing clamps (Parker-Kerr) are placed to arch above the ulcer.

The Polya type of operation.—In the operations which fall into this group the duodenum is closed and the cut end of the stomach is implanted into the side of a loop of jejunum. These operations showed an advance upon the Billroth II operation, which was in vogue at the time of their introduction. The Polya procedure made it possible to remove more stomach, and the danger in the Billroth II method



Fig. 346.—Polya partial gastrectomy. Duodenum divided and closed. Seromuscular suture completed between open end of stomach and a loop of jejunum.

(that the opening for the gastro-enterostomy might by dividing vessels devitalize the tissue at the site of the closed stump) was abolished.

Polya gastrectomy. Technique.—The early stages of this operation are similar to those of the Billroth I operation up to the mobilization of the duodenum. The duodenum is then clamped with two Payr clamps, the organ is divided between them and the stomach is drawn out of the way over to the left.

The duodenum is now closed. This may be effected in several

ways. A suture of fine linen, silk or catgut is inserted under the tip of the Payr clamp at the superior surface of the duodenum and tied. This is now continued along the cut edge of the duodenum as a continuous suture passing through all the coats, until the lower border is reached. The suture should not be pulled tightly round the Payr clamp or it will prevent easy removal of the latter; as a precaution it is useful to hold a long artery forceps over the Payr clamp and draw each loop of the continuous stitch over it. The artery forceps is removed and the duodenal stump surrounded with an abdominal pack. The Payr clamp is now opened and withdrawn gently, and it will be found in 19 cases out of 20 that the crushing of the duodenal cut end has been so effective that there is no escape of duodenal contents. The continuous stitch is now drawn tight, loop by loop, and tied. This suture line is now embedded by a second suture passing through the seromuscular coats, either a continuous Lembert, or a purse string. Alternatively, the duodenum may be crushed and ligatured, and embedded with one or two purse string sutures. Next a stitch takes a bite, in turn, of right gastric pedicle, anterior surface of the duodenum, right gastro-epiploic pedicle and the peritoneum over the pancreas. When this is drawn tight the duodenal stump is covered and the raw areas are greatly diminished. The stomach is then further mobilized as in the Billroth method.

The mesocolon is inspected to discover a satisfactory avascular area in it and an opening is made, through which a loop of proximal jejunum is drawn and clamped at the proposed site of anastomosis. It is better for the afferent jejunum to be approximated to the lesser curve side of the stomach and this loop should be just long enough to reach the lesser curvature without tension. It will usually be three to four inches in length. The amount of jejunum held in the non-crushing clamp should be slightly longer than the diameter of the stomach. The two clamps are now approximated or locked side by side. The area is surrounded by packs and the anti-soiling towel as described in "gastro-jejunostomy". The union between stomach and jejunum may be made by making an opening equivalent either to the whole diameter of the stomach as in the original Polya operation or to a part of it (Hofmeister, Finsterer, Lake) (Fig. 846). The size of the opening has little effect on the rate of emptying, so long as the stoma is wider than the jejunal diameter, for the rate of emptying is mainly dependent on the diameter, tonus and peristaltic activity of the jejunum. There is no doubt, however, that a stoma as wide as the stomach is unnecessarily large. By the modification to be described a stoma is made adjacent to the greater curvature, one-half or one-third of the gastric diameter in size. This involves less suturing than is required for the wider stoma and avoids gastro-jejunal anastomosis to the more inaccessible and less well peritonealized lesser curve of the stomach. Closing part of the lesser curvature side of the gastric diameter has the additional advantage that it diminishes the tendency of the gastric chyme to enter the afferent jejunal loop.

When the stomach and jejunum are secure in their clamps they are united by a continuous seromuscular suture which is started at the greater curve and is interrupted at the lesser curve of the stomach, where a lock stitch is made (Fig. 346). The stomach is now lifted up

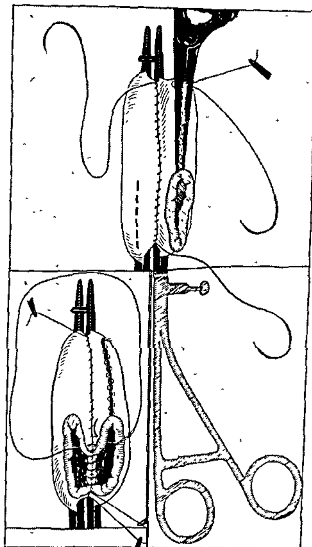


Fig. 347.—"Valved" Polya partial gastrectomy. The posterior surface of the stomach has been united to the jejunal loop by a continuous seromuscular suture. The upper half of stomach is occluded by a Payr clamp and is closed by through and through continuous or "sewing machine" stitch. The lower part which has been left open is to be united to jejunum as indicated.

and a crushing (Payr) clamp is placed across it about a third of an inch distal to the seromuscular suture line, and extending from the lesser curve for half to two-thirds of the diameter of the stomach. Beyond this a light non-crushing clamp is placed across the stomach, to prevent soiling. The stomach is transected and removed, the division being

immediately distal to the Payr clamp on the lesser curve part of the stomach, and a little farther from the seromuscular suture line on the unclamped greater curve part.

The part of the gastric lumen held in the Payr clamp is now closed by a continuous catgut suture, either run loosely round the Payr clamp as described in closure of the duodenal stump, or by a catgut "sewing machine" stitch which is run tightly under the clamp (Fig. 847). The Payr clamp is then removed and the sutures tightened and tied. This leaves a small opening in the stomach and an opening of similar length is now made in the adjacent jejunum. The open parts of jejunum and stomach are now united by a continuous "all the coats" catgut stitch which starts at the greater curve of the stomach (Fig. 847), and after uniting the posterior walls turns the corner and then unites the anterior walls in a similar fashion to that employed in [illegible] (p. 807). The packs, towels, clamps an[illegible] removed and the surgeon's and ass[illegible]s gloves changed or washed. The seromuscular suture which united the posterior walls of the stomach and jejunum is now continued round the lesser curve of the stomach and jejunum, and then covers first the closed end of the stomach and next the gastro-jejunal anastomosis by uniting the anterior seromuscular coats of stomach and jejunum. It is finally tied to its commencement at the greater curvature. An extra stitch or two is now placed between the lesser curve of the stomach and the afferent jejunum in such a way as to hitch up the jejunum to cover the unperitonealized lesser curve. These stitches also serve to take the tension off the anastomosis and to diminish further the likelihood of gastric contents entering the afferent jejunal loop.

When the anastomosis is completed the transverse colon is turned up, the jejunum and stomach are drawn down and the edges of the mesocolon are fixed to the stomach just above the anastomosis. Although this manœuvre is described now for the sake of clarity, it is easier to place the stitches between the posterior wall of the stomach and adjacent mesocolon immediately after application of the non-crushing clamp to the stomach and prior to making the gastro-jejunal anastomosis.

This operation may equally well (or, in the writer's opinion, better) be carried out as an antecolic operation, in which case the afferent loop should be only an inch longer. Too long (12–18 inches) an afferent loop occasionally causes trouble by rotating behind its own mesentery and becoming obstructed On the other hand in the retro-colic anastomosis obstruction of the afferent or efferent loop may occasionally result from an insecurely fixed mesocolon sliding down over them. Alternatively an antecolic anastomosis may be made uniting the afferent loop to the greater curvature (Moynihan operation) After any antecolic anastomosis the transverse colon should be drawn to the right at the completion of the operation, so that the antecolic loop will be in front of the well-supported splenic flexure of the colon and not have the weight of

the transverse colon upon it. As with gastro-jejunostomy, it is unsafe to use methods such as the Roux modification, or to short-circuit the afferent and efferent loops, because these operations cause a diversion of the alkaline duodenal secretions from the stomach and may lead to gastro-jejunal ulceration. In fact they are similar to the methods used by Mann and Williamson to produce experimental ulcers in animals.

DIFFICULTIES IN GASTRECTOMY

Penetrating ulcers.—Occasionally difficulty is experienced in dealing with ulcers which penetrate into organs neighbouring on the stomach, most commonly pancreas or liver. They may be dealt with as follows.

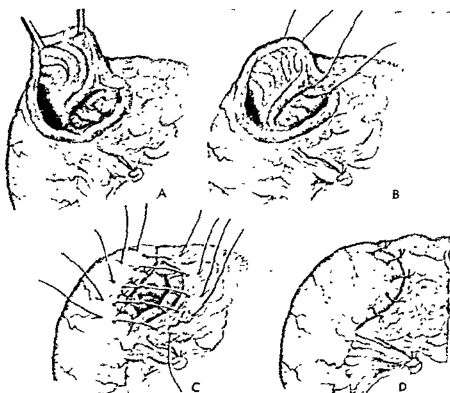


Fig. 348.—Method of dealing with difficult position penetrating duodenal ulcer. A, The duodenum has been transected opposite the proximal edge of the ulcer. B, Sutures are placed between the cut edge of the duodenum and the distal ulcer edge until good closure is obtained. C and D, Interrupted sutures are placed between the seromuscular coat of the duodenum and proximal ulcer edge or adjacent fibrotic pancreas.

In the cases of gastric ulcer, the duodenum is divided and the stomach is turned over to the left to expose the adherent area. This is surrounded with packs and then the stomach and the penetrated organs are separated by squeezing the adhesions between finger and thumb thus "pinching off" the adherent margins. Usually the parts separate with ease, occasionally a scalpel or scissors is required. When separate, the base of the crater is seen in the invaded organ

and a round opening—the ulcer edge—is seen in the stomach. The stomach contents are aspirated and the opening in the stomach is temporarily sutured by a strong continuous suture to prevent further soiling with gastric content, after which the resection proceeds as described. It must be emphasized that it is unnecessary and in fact dangerous to cauterize or attempt to remove the ulcer floor which remains in the pancreas, though it may be swabbed clean and dusted with a little antiseptic powder.

When the posterior wall of the duodenum is involved the technical difficulties of duodenal mobilization are greatly increased, and clamps cannot be used. By slow and painstaking dissection, however, enough duodenum may be dissected beyond the ulcer to allow of duodenal closure. At times it is necessary to place sutures between the anterior cut surface of the duodenum and the edge of the duodenal crater posteriorly, for fear that further duodenal dissection, with the object of removing the whole crater, may endanger the bile ducts. In such a case the eventual closure may be strengthened by placing interrupted sutures of fine silk between the seromuscular layer of the duodenum anteriorly and the pancreas, or even the edge of the ulcer crater, posteriorly (Fig. 348). If doubt is felt as to the security of the closure, a small drain may be placed down to the neighbourhood of the duodenum. In cases of extreme severity it may be impossible to close the duodenum, and a tube should then be stitched into its lumen and brought directly through the parietal incision, thus deliberately making a temporary duodenal fistula.

Irremovable duodenal ulcer.—In cases where grave difficulty is anticipated in dealing with the duodenum it has been suggested that the pyloric antrum be transected in such a way that the antrum may be easily closed and then a gastrectomy removing only the body of the stomach performed. As mentioned (p. 796) this procedure led to a very high incidence of anastomotic ulceration. If, however, instead of leaving the antrum intact its mucosa is removed, as far as the commencement of the duodenal mucosa, and the seromuscular coats of the antrum then closed, then the operation is not followed by anastomotic ulceration.*

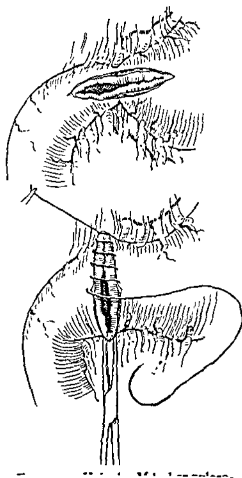
Other ways of dealing with such difficulties are (1) to perform a gastrectomy conserving the antrum, removing the antrum two months later, or (2) to perform gastro-jejunostomy, with or without vagotomy. The former is especially valuable for the less experienced surgeon confronted with a very difficult case.

Pyloroplasty and Gastro-Duodenostomy

Pyloroplasty, gastro-duodenostomy, and operations in which pyloroplasty was combined with excision of the ulcer used to be widely performed, though they have never become very popular in this country. As a means of dealing with active duodenal or pyloric

* Wolfson and Rothenberg, 1938, *Surgery*, iii, 663.

ulcer they are now considered ineffective. Occasionally these procedures are of use in dealing with stricture formation resulting from healed ulceration. More recently *pyloroplasty has been found* in some hands to prevent or relieve the retention symptoms which may follow vagotomy. A modified pyloroplasty is occasionally helpful when dealing with a perforated stenosed duodenal ulcer, as an alternative to gastro-enterostomy in the prevention of post-operative gastric obstruction. Perhaps another point in favour of keeping the operation of pyloroplasty in the text-books is the fact that the operation, particularly the Heineke-Mikulicz method, embodies a principle which may be used in the treatment of strictures in any part of the alimentary tract.



[illegible] pylorus and closed by suture in the vertical direction.

Pyloroplasty. Technique. — The simplest of these operations is that known as the Heineke-Mikulicz operation. A longitudinal incision about 6 cm. long is made in the anterior wall of the pyloric canal and first part of the duodenum (Fig. 849). The incision should lie midway between the greater and lesser curvatures and all coats are divided. The incision may be made to encircle an adjacent anterior duodenal ulcer or cut through a duodenal narrowing resulting from healed ulceration. The walls of this longitudinal opening are drawn *apart from the centre until it* becomes vertical, when the opening is stitched transversely with two layers of continuous or interrupted stitches. Great care must be taken to tuck in the extremities of the incision and it is important for the surgeon to realize the comparative thinness of the duodenal wall. If there is any doubt about the integrity of the suture line it may be protected by an omental graft

Gastro-duodenostomy.—In this operation either the pyloric canal is much widened or a new communication is made between the stomach and duodenum. In the operations of Jaboulay and Kocher, and later that advocated by Balfour, a direct communication was made between the dilated stomach and the duodenum below the stenosed pylorus, but the operation which has been most in vogue is *that of Finney.*

The first essential in this operation is thorough mobilization of the pylorus and of the first and second parts of the duodenum, by dividing the peritoneum and fascia propria lateral to the duodenum and with the fingers in the retroperitoneal cellular tissue gently lifting the duodenum and drawing it medially. A point on the greater curve of the stomach about three to four inches proximal to the pylorus is

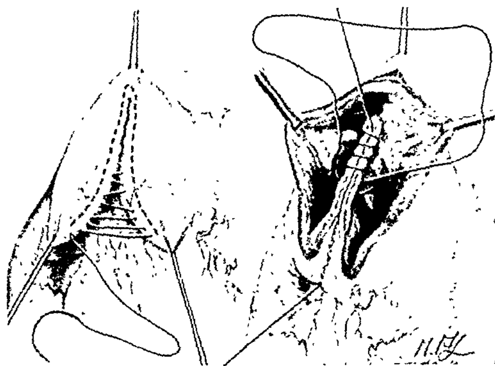


Fig. 350.—Finney pyloroplasty. The adjacent prepyloric position of the stomach and the mobilized duodenum are united by seromuscular suture. An inverted U-shaped incision is then made and the edges united by continuous "all coats" suture.

now anchored by a stitch to the corresponding point on the medial side of the second part of the duodenum, below the level of the Ampulla of Vater. After suitable packing off, the two parts are united with a seromuscular suture, for a distance of about two inches downwards An inverted U-shaped incision is next made just outside the suture line, passing from stomach across pylorus onto the duodenum (Fig. 350) and thereby opening both viscera The cut edges of stomach and duodenum are united and the anastomosis completed by an anterior seromuscular suture. The final result is of course not unlike a vastly extended Heineke-Mikulicz pyloroplasty.

Results.—These operations are occasionally of value when one of the indications mentioned are present. If used as a method of dealing with active duodenal ulcer whether acute or chronic a very high rate of local recurrent ulceration may be anticipated.

Vagotomy

This operation involves division of all the nerve fibres of both vagus nerves before they reach the stomach, with the object of removing the stimulating effect of these important nerves on the secretion of peptic juice (*see* p. 785). It has been found, experimentally and clinically, that partial interruption of the nerves has an uncertain effect, and complete division is essential. In order to make the effect permanent, and prevent regeneration of the nerve fibres it is necessary to excise a length of the nerve. The operation might therefore be more correctly described as a vagus nerve resection or vagectomy.

The nerves may be approached either by the abdominal or the transpleural route, but the latter has become less used owing to the following disadvantages:—

1. The higher morbidity associated with the transpleural approach.
2. The necessity for the removal of pleural exudates post-operatively.
3. The inability to confirm the diagnosis, or carry out any other operation on the stomach at the same time.
4. The occasional development of post-operative intercostal neuralgic pains which may be severe and prolonged.

The third reason may be especially important when operating for recurrent ulcer, for in such cases there may also be mechanical faults requiring correction.

The transpleural approach is advisable, however, if it is known that there are dense adhesions which will make laparotomy hazardous, or if there is a hiatus hernia with œsophageal shortening.

Transpleural vagotomy.—The approach may be made through either the right or left pleural cavity, though the left approach has the advantage that if necessary the stomach may also be reached and *dealt with by incising the diaphragm.*

The patient is placed on the side in the usual position for postero-lateral thoracotomy, and the chest opened by an eight to ten inch long incision through the 7th, 8th or 9th intercostal spaces, or through a rib bed after removal of the bone. The pleural cavity is widely opened with a rib spreader (*see* p. 849; also Chapter VII for general technique of thoracic operations).

The lung is retracted forwards and a vertical incision made through the pleura in front of the aorta extending from the arch to the diaphragm. After freeing the edges of the cut pleura the œsophagus is found and mobilized, and a broad tape placed round it, to steady it and to act as a tractor.

The nerves may be conveniently found just below the tracheal bifurcation usually lying antero-laterally on either side of the œsophagus where they can be identified by their position and by palpation. From here the nerves and plexuses into which they divide are dissected

downwards until they each form one or two discrete trunks again, at a varying distance from the œsophageal hiatus in the diaphragm. It is probably a wise precaution to infiltrate with local anæsthetic around the upper part of the nerves at the commencement of the dissection. The nerves are now divided just below the tacheal bifurcation. The cardia is drawn upwards and the lower ends of the nerves are divided as near to the stomach as possible, the intervening portion being removed. Any bleeding points are ligatured. It is unnecessary and unwise to divide any well marked vessels passing from the aorta to the œsophagus. The pleura overlying the œsophagus is now closed with find interrupted sutures, the lung reinflated, and the thoracotomy wound closed in the usual way. Pleural drainage is usually unnecessary.

Complications and post-operative care.—Accidental damage to the opposite pleura is rare but if it occurs the edges should be caught and the rent ligatured or sutured. If the puncture cannot be repaired the anæsthetist will need to keep the lung inflated until the chest is completely closed. Damage to the œsophagus should be treated by immediate repair. If the thoracic duct is injured both ends should be ligatured. The post-operative care for vagotomy will be required as described later, also the routine care after transthoracic operations (*see* pp. 880, 861), aspiration of any effusion of blood from the pleural cavity being particularly important. In the event of a torn thoracic duct with chyle accumulation in the pleural cavity free drainage by tube is essential and usually successful.

Transabdominal vagotomy.—The writer prefers a high midline or paramedian incision extending up into the costo-sternal angle. Some surgeons use a transverse incision. On opening the abdomen the presence of ulcer is confirmed by inspection and palpation. It must again be emphasized that vagotomy is of no value for non-ulcerative or functional dyspepsias. If duodenal ulceration is present the diminished motor powers of the stomach which will follow vagotomy make it advisable to combine a pyloroplasty, gastro-jejunostomy or gastrectomy with the vagotomy. If the condition is one of stomal ulceration, no further procedure is necessary unless there is narrowing or gross deformity of the stoma, in which case a plastic operation or reformation of the stoma will be advisable. If some such procedure is to be added, it is well to perform the vagotomy first in order to reduce the risk of soiling the mediastinal tissues.

A retractor is placed under the left costal margin. The first step is to mobilize and displace the left lobe of the liver. The surgeon, standing on the right side of the patient, places two fingers of his left hand on either side of the left triangular ligament of the liver and draws the left lobe of the liver downwards. The ligament thus displayed is divided with long scissors until the division extends to the right side of the œsophagus. The left lobe of the liver is then turned

downwards and to the right to lie under the right lobe where it is held by a long liver retractor placed under the right costal margin.

On drawing the stomach firmly downwards, the region of the œsophago-gastric junction is brought into view, though the œsophagus is of course not yet seen. Its position is verified by palpation (this is made more easy if a *large firm rubber tube has been passed down its* lumen). A transverse incision is now made through the peritoneum in



Fig. 351.—Abdominal vagotomy. After division of the peritoneum and the diaphragmatico-œsophageal ligament, the muscular wall of the œsophagus comes into view.

front of the lowest, i.e. abdominal, œsophagus. Under this is seen an aponeurosis, the diaphragmatico-œsophageal ligament, which is a continuation of diaphragmatic fascia into the cardiac region. This aponeurosis is divided in the same line, taking care not to cut too [illegible] œsophagus comes into view (Fig. 351). *The œsophagus* [illegible] ger round it. It is usually recom- [illegible] e placed round the œsophagus to steady it and to bring the vagus nerves well into view To my mind

this may damage the œsophagus and is particularly undesirable in view of the risk of post-vagotomy cardiospasm. Consequently I prefer to place a tube or long strip of corrugated rubber as follows:—

The left index finger is placed through the peritoneal incision just to the left of the œsophagus and this finger works its way downwards behind the bare area of the upper stomach. The left thumb is pushed through the gastro-hepatic omentum below the left gastric pedicle

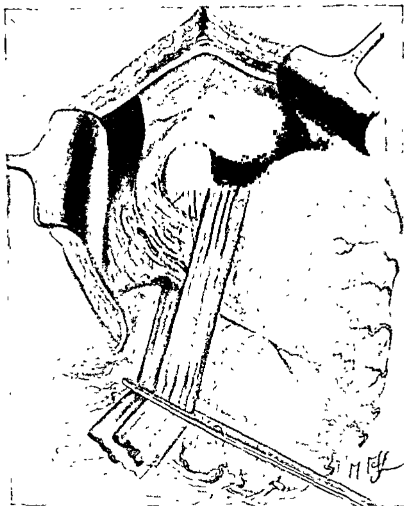


Fig. 352—Abdominal vagotomy. By employing the writer's method of peri-gastric traction the three main divisions of the interior gastric (vagus) nerve are brought into view.

into the lesser sac and passes upwards to meet the index, so that only a single layer of peritoneum, the roof of the lesser sac, lies between them. A Moynihan cholecystectomy forceps is passed into the lesser sac to accompany the thumb and is thrust through the roof of the lesser sac and is guided by the index finger until its point appears just above the incisura cardiaca. The end of a long thin strip of corrugated rubber is placed in the teeth of the forceps and the forceps withdrawn The ends of the rubber are gripped with an artery forceps

and this forms an excellent peri-gastric tractor to draw the œsophagus downwards without exerting any direct pressure upon it. In addition it allows the surgeon to dissect the vagus branches farther down on to the stomach, and to observe the branches passing medially to the lesser curve and liver (Fig. 352). Gentle traction is now exerted on the rubber strip with the assistant's left hand and the cardio-œsophageal region is thus steadied and brought into view.

On inspection of the anterior surface of the lowest œsophagus the anterior gastric nerve is seen, or perhaps felt as a tense cord. A Moynihan or other suitable long angled forceps is clamped on the nerve near the stomach and the nerve then lifted upwards. The nerve is dissected and followed peripherally until it is seen to break into three branches (one passing towards the liver hilum, one along the anterior part of the lesser curve of the stomach and one on to the anterior surface of the stomach). If the three branches are not seen it is probable that the anterior nerve is not one but two or more nerves and accessory nerves should be searched for with care. The three branches are divided as low as possible. The nerve is then pulled downwards and is dissected well up into the posterior mediastinum. It is emphasized that it is the nerve and not the œsophagus which is mobilized, for if the œsophagus is separated from its surroundings some of its blood supply may be damaged. A narrow retractor is placed into the posterior mediastinum under the anterior part of the œsophageal hiatus of the diaphragm and a second long angled forceps applied to the nerve as high as possible. This serves to steady the nerve and protect the other structures in the mediastinum, while with long curved scissors the nerve is cut across just below the forceps which may then be loosened and removed. By this means the whole of the isolated portion of nerve is excised.

The posterior nerve is found by steady downward traction on the rubber retractor, thus making the nerve tense and cord-like, the left index finger being passed behind the œsophagus to find it. The finger may insinuate itself behind the nerve, or between œsophagus and nerve. When isolated the nerve is drawn into view to the right of the œsophagus and clamped low down with a forceps. At times it is possible to find or palpate the normal three branches of the posterior nerve (which pass towards the cœliac artery, posterior part of the lesser curvature and posterior surface of the stomach respectively), but often this is not possible This posterior nerve is dealt with in the same way as the anterior A careful search is made for any branches that may have been missed Any suspicious tense strands which may be nerve tissue, but which are usually fibrous or muscle tissue, should be severed Sometimes branches may be felt away from the œsophagus, or even in the œsophageal musculature. Usually it is possible to remove some 5–6 cm. of each nerve.

Repair after vagotomy.—*Having divided the aponeurosis extending* from diaphragm to cardia—the so-called diaphragmatico-œsophageal

ligament—a wide opening into the mediastinum is left, which might later allow of the development of hiatus hernia. To guard against such an event the edges of the divided ligament and peritoneum—not the peritoneum alone be it noted—are carefully re-sutured with three to four interrupted silk sutures. The rubber retractor is removed and the left lobe of the liver allowed to re-assume its normal position. Any necessary operation on the stomach, e.g. pyloroplasty or gastro-jejunostomy, is now performed and the abdominal incision closed.

POST-OPERATIVE CARE AFTER STOMACH OPERATIONS

Shock does not generally follow these operations, though it may occasionally occur after major gastric resections. In such cases blood or plasma transfusion will usually have been started during operation and should be continued post-operatively. Morphia should be given immediately there are signs of awakening to discomfort. Patients are usually put into a semi-recumbent position as soon as they recovered from the anæsthetic, as it makes breathing and coughing easier and deeper, and lessens the tendency to vomiting.

Feeding.—There is a tendency for the stomach and intestine to be paretic for between 6 and 24 hours after operation, and even longer in the presence of peritonitis. As a result, administration of much fluid in the first hours will merely lead to gastric distension and by causing loss of gastric tonus may tend to increase the ileus. For these reasons only small quantities of fluid are given by mouth during the first 24 hours. A slow rectal saline or tap-water infusion will usually be absorbed. Thereafter, water and fruit juices may be given in quantities sufficient to prevent thirst up to about six ounces every two hours. On the third day, milk and egg may be given, for protein is urgently needed to promote wound healing. Easily digested solid foods are given from the fourth day, i.e. thin bread and butter, eggs, custards, jellies, etc., and fish, minced meat and poultry are permissible by the fifth day. Thereafter a normal diet is instituted.

Stomach tube.—To ensure against gastric over-distension, a Ryle or thin œsophageal tube is introduced into the stomach, either before or shortly after operation. Gentle aspiration every four hours on the first day will guard against gastric distension and make it permissible for larger quantities to be drunk. It also gives an indication of the extent of bleeding from the suture line A small quantity of altered blood resembling coffee grounds is normally present On the second and third days, aspiration on two or three occasions is enough and the tube may be removed after each aspiration. Thereafter it may be used with advantage if the patient complains of nausea, epigastric discomfort, or appears unwell without explanation.

Bowels.—It is unnecessary to give strong aperients. A flatus tube is used after the first day. As soon as any flatus is passed, or any

intestinal colic is noticed, usually about the third day, an enema is given. Thereafter, regular glycerine enemata or mild aperients may be given until a normal bowel habit is regained.

Prevention of chest complications.—Minor degrees of pulmonary collapse may occur, and occasionally lung infections. The incidence of these troubles may be diminished by encouraging deep breathing before and after operation, and the coughing up of any bronchial secretions, particularly if there is a " fruity " type of cough. The patient will cough with more confidence if a nurse or attendant supports the area of the wound with the palms of the hands during these exertions. If pulmonary collapse occurs then coughing with the head of the bed lowered, and the patient lying with the impaired lung uppermost, particularly after a dose of morphia, may lead to expulsion of the obstructing mucus. Intravenous nikethamide injection may help to promote a more productive cough. If this fails it may be helpful to try to aspirate the mucus with a No 16 French catheter introduced into the trachea. This may be done as follows The patient is propped up with head extended and a small quantity, 1–1·5 c.c., of surface anæsthetic, e g. 2 per cent amethocaine hydrochloride, is introduced, ½ c.c. at a time, into the nostril with the better airway. The rubber catheter is attached to one limb of a Y-shaped glass connection, an electric " sucker " is attached to the stem and finger pressure on the second limb may be used to give intermittent aspiration. The tube is introduced into the nose, and during deep inspiration an attempt is made to guide it blindly through the glottis into the trachea. Aspiration from time to time leads to useful coughing and purulent bronchial secretions may be aspirated. The tube may be directed into the right or left main bronchus by rotating the head and neck slightly in the opposite direction. If this procedure fails then bronchoscopic aspiration may be necessary.

Pre- and post-operative routine chemotherapy using penicillin diminishes the incidence of pulmonary infection and should be used in feeble patients or patients with chronic pulmonary infection.

Early ambulation.—The average case should be permitted to sit out of bed while the bed is made on or about the third day, though feeble patients should not be urged to get up if their condition is poor. This may diminish the incidence of thrombotic complications In any case the patient is encouraged to move his feet and legs, arms and trunk freely in bed, and perform breathing exercises several times daily It is the writer's practice to put these patients in the hands of a physiotherapist before operation, so that all these exercises are carried out as a routine both before and after operation

Special after care for the vagotomy operation.—Gastric atony is particularly marked after vagus nerve resection Without special care severe gastric and intestinal distension is very likely to occur and may lead to dehydration and even death. Therefore, four hourly or continuous gastric aspiration is continued for three to four days after

operation, though the frequency may sometimes be diminished when there are signs that the stomach has commenced to empty satisfactorily. It is of course essential to administer adequate daily intravenous glucose and saline to prevent dehydration. If prolonged aspiration is required hypokalemia may occur, and so the blood potassium level should be estimated. If it is low potassium chloride 3 gm to the litre, should be given very slowly by the intravenous route until a normal level is reached.

Early Post-Operative Abdominal Complications

Hæmorrhage from the gastric suture line, gastric or gastro-jejunal ileus, suture line leakage and diarrhœa are the abdominal complications mainly to be feared. Rarer complications include peritonitis, intra-peritoneal bleeding, wound disruption, pancreatic leakage.

Early hæmorrhage within a few hours is usually the result of failure of the " all the coats " suture to control the bleeding points. Bleeding, occurring a few days post-operatively, may be from multiple erosions. The extent of the bleeding can be judged by the pulse rate, the nature of the stomach contents aspirated at regular intervals, the vomiting of clots, and by the amount and brightness of any melæna. A single hæmatemesis should be treated with morphia and immediate slow drip blood transfusion. Usually the bleeding ceases spontaneously. If severe bleeding continues, then the abdomen must be re-opened and the stomach exposed and explored. An independent incision is made into an accessible part of the anterior stomach wall and the suture line inspected. A single bleeding vessel may be caught and tied or several bleeding points firmly underrun with mattress sutures of catgut. The gastrotomy wound is carefully closed and the parietal wound re-sutured using some through and through sutures.

Post-operative gastric, or even general intestinal distension or ileus, is a rarity if the indwelling gastric catheter is used freely. Before its regular use gastric dilatation, persistent vomiting and dehydration were not uncommon. Some cases were due to exaggeration of the normal ileus which follows operation on any part of the bowel, some to acute dilatation of the stomach, some may have been due to " vicious circle " vomiting. The latter is nowadays believed to be due to obstruction of the jejunal loops by an unfixed or inadequately fixed edge of the mesocolon. The treatment in either case, however, is to aspirate the gastric content continuously and correct the dehydration with intravenous saline. Dramatic improvement usually results, unless there is some mechanical obstruction. If shock, abdominal colic or local tenderness develop, the surgeon should suspect a mechanical obstruction, such as a band or adhesion, or obstruction of the afferent loop of an antecolic gastrectomy. Plain X-ray may show the extent of any dilated bowel, and auscultation of the abdomen may help to differentiate between bowel paralysis and obstruction. If epigastric pain going through to the back occurs after an antecolic gastrectomy, and bile is persistently absent from the gastric aspirate, one may

suspect obstruction of the afferent loop. This is sometimes relieved by putting the patient in the Trendelenburg position or on one or other side, and relief may be confirmed by the diminution of pain and reappearance of bile in the gastric content. Pancreatitis should be excluded by a blood and urine amylase estimation. If no relief is obtained laparotomy may be necessary to deal with the mechanical obstruction. Enteroanastomosis between the loops of small bowel leaving the stomach has often been a late but lifesaving measure.

Suture line leakage, either from the duodenal stump or from the gastro-jejunal stoma may occur but is fortunately rare. The writer believes that both can be prevented by a careful and painstaking technique and in a personal series of about 1,500 gastrectomies for ulcer such a leakage has been unknown. A leakage in the absence of a drain may lead to local or general peritonitis. In such a case, if the patient can be made fit for laparotomy, the abdomen should be explored, and fluid aspirated or mopped from the peritoneal cavity. If the leak is at the stoma it must be repaired by suture and covered with a tag of omentum and drainage by a rubber strand arranged from the site. If the duodenal stump is leaking it should be drained, and continuous gentle suction made from the drainage tube. Needless to say, the skin must be protected before it becomes excoriated, e g. by aluminium paint, and dehydration prevented by intravenous saline infusion, blood and plasma transfusion. If the fistula persists as a result of afferent loop obstruction, reoperation with a view to anastomosis of afferent and efferent loops will be necessary.

Post-operative diarrhœa mainly occurs after high gastrectomy, or after vagotomy. In both cases the ætiological factor is probably the achlorhydria and so the condition is akin to gastrogenous diarrhœa and may be due to infection following the loss of the acid antiseptic barrier. In either case a combination of acid mixtures (e.g. acid hydrochlor dil. dr. 2 q.q.h. in water or lemonade) and sulphathalidine will usually result in early control. A starch and opium enema will often give a few hours' relief of diarrhœa. Dehydration must of course be treated by intravenous therapy.

Cardiospasm following vagotomy.—A few days, or a week or more, after vagotomy difficulty in swallowing may arise. X-ray of a barium swallow may disclose an obstruction at the cardia identical with that noted in early cardiospasm. This may be treated by the passage of Hurst mercury filled bougies, or by octyl nitrate, and usually responds readily.

Late complications of operation on the stomach and duodenum are dealt with as follows —

Gastro-jejunal ulcer, gastro-colic fistula (p. 839).
Retrograde jejuno-gastric intussusception (p. 843).
" Post Cibal " symptoms (p. 843)
Late post-vagotomy symptoms (p 844).

Complications of Peptic Ulcer

Perforation.—At one time it was considered that this complication was almost inevitably fatal unless early operation was performed, though very occasional recoveries without operation were seen.* Lately, however,† conservative treatment of early perforations has been tried on a sufficiently large scale to show that its results may bear comparison with those obtained by surgery. The conservative regime involves emptying the stomach of its contents with a large bore tube, and thereafter continuing gastric aspiration through a smaller indwelling stomach tube (Ryle's tube). Morphia, intravenous saline and glucose, and if required blood and plasma, are also given and feeding is instituted gradually. The consensus of opinion is still in favour of surgery, for by the conservative regime an occasional young subject with an early perforation is lost, a state of affairs which is nowadays very rare with early surgery. Further, the conservative regime may be disastrous if the diagnosis is incorrect.

As regards the nature of the operation to be performed, most British surgeons favour simple closure of the perforation and nothing more. In some clinics there is a move in favour of immediate gastrectomy in the treatment of perforated peptic ulcer. Good results may be obtained by this method, and it is undoubtedly an advantage to be rid of a chronic peptic ulcer. In the hands of the writer and of many of his colleagues urgent gastrectomy has proved quite as safe as simple suture and perhaps safer. Its main advantage, however, is that further ulcer symptoms and complications are usually prevented. Partial gastrectomy for perforated ulcer should be carried out in those cases associated with bleeding, or in which malignancy is strongly suspected. In other cases of ulcer perforation gastrectomy may be used if the surgeon is very skilled in the operation, the patient in reasonably good condition, and the ulcer one with a chronic history, particularly if the ulcer is gastric. Less experienced operators should content themselves with simple closure of the perforation, and this is always the most suitable procedure when perforated acute ulcers are being dealt with.

Preparation.—When the diagnosis of perforation has been made and it has been decided to operate, nothing should be given by mouth, and morphia, ¼ gr., should be administered hypodermically. When necessary, time should be taken to give intravenous saline and to allow the patient to recover from the pain and shock of the perforation, and of his journey to hospital.

Operative technique.—A general anæsthetic is preferable, though in [illegible] of [illegible] th [illegible] flu [illegible] escape and a sucker should be introduced to remove

* G. Grey Turner, *Lancet*, 1946, ii, 693.
† H. Taylor, *Lancet*, 1946, ii, 444.

the excess of fluid. The *perforation* is as a rule easily found on the anterior surface of the stomach or duodenum. If it is not seen there, the *posterior surface of the stomach and duodenum* is inspected after opening the lesser sac through the gastro-hepatic or gastro-colic *omentum*. The perforation having been located, it is closed by a series of Lembert stitches passed sufficiently far from the perforation to take generous " bites " of healthy tissues. When these are tied the whole ulcer and perforation are infolded (Fig. 353). Alternatively



Fig. 353.—Method of suturing a perforated gastric ulcer.

a purse string suture may be used if this does not constrict the viscus. *Where the tissues are poor and closure difficult, it is advisable to* bring up tags of omentum or part of a neighbouring viscus to cover *the sutured area, and an extra stitch or two may be used to strengthen* any doubtful point. If closure of the perforation appears to be impossible by the above means *gastrectomy may be performed or the* perforation simply plugged with omentum, or a catheter may be passed through the perforation into the stomach, converting it into a gastrostomy * The latter procedure has the advantage of providing a safety valve against post-operative distension and a means of giving intragastric drip feeding.

If there is coincident severe ulcer hæmatemesis and melæna, or the peritoneal cavity is full of blood from the stomach—then immediate partial gastrectomy is advisable.

On occasions perforation may occur in patients who already have symptoms of duodenal stenosis. In such cases it is well to perform

* G Grey Turner, *Lancet*, 1937, Feb 6th

gastro-enterostomy before closing the abdomen. Better still, particularly if the duodenum is mobile and the patient in good condition, partial gastrectomy may be carried out or the ulcer may be excised and pyloroplasty performed.

Apart from such a complication gastro-jejunostomy is not advisable, for it does not lower the mortality, and retention should rarely or never be caused by the mere suturing of a perforation.

When the perforation has been dealt with the excess of exudate is gently aspirated from the pelvis. Except in cases of perforation in the presence of pyloric stenosis, or late perforation in which general peritonitis had developed, suprapubic peritoneal drainage is probably unnecessary. Local chemotherapy in the way of antiseptic dusting powders may sometimes be helpful but should be used sparingly.

The wound is closed in the usual way, but two or three through and through tension sutures of stout insoluble material should be added in case the wound becomes infected and tends to disrupt.

The patient is nursed at first in the Fowler or semi-recumbent position. After operation sips of water may be given in the first 24 hours if there is thirst, and periodic gastric aspiration employed during this period. Rectal or intravenous saline is advisable. After this diet is gradually instituted as for gastrectomy. General chemotherapy, as described for gastrectomy, helps to diminish post-operative infective complications.

Complications.—The most frequent complication is subphrenic abscess, which may occur in any of the six subphrenic spaces, but generally arises in the right or left anterior intraperitoneal space. Abscess formation may occur in other parts of the peritoneal cavity, particularly the pelvis. Local infection may lead to the development of gastric or duodenal fistula. These complications have become less frequent since the introduction of the more potent chemotherapeutic drugs.

Shock, peritonitis and ileus are more common than with other gastric lesions owing to the infection. Disruption of the wound may occur as a result of the poor general condition of the patient, combined with infection. Hæmorrhage from the ulcer after closure of a perforation, though not common, may occur and is treated on the usual lines, surgery being frequently required. Pulmonary complications are frequent and these probably result from poor diaphragmatic movement in the period after perforation and bear little relation to the form of anæsthesia or anæsthetic agent.

Results.—In perforated gastric or duodenal ulcer the result depends mainly on the delay between perforation and operation. In 1937 Grey Turner reported 450 cases operated on within twelve hours with a mortality of 9·55 per cent., and of these 247 were operated on within six hours with a mortality of 4·4 per cent *

There has been a tendency for the mortality as a whole to diminish

* G Grey Turner, *Proc. Roy Soc. Med*, Surgical Section, 1937.

of late years; for example, Professor Illingworth and his team from West Scotland* record a general mortality of 19·5 per cent. in 7,156 cases. The mortality was 25·7 per cent. in 1924 and 14·1 per cent. in 1948. F. A. Jones, P. J. Parsons and B. White,† in analysing 490 cases of acute perforation treated from 1938 to 1948, found that during the first three years the mortality was 27 per cent. and in the last two years 10 per cent. (In those fit for operation the mortality was only 4 per cent.) Figures like these must be borne in mind when new methods of treatment are being considered.

H. Taylor‡ treated 28 consecutive cases of perforated peptic ulcer conservatively with four deaths (i.e. 14·3 per cent.).

There has been considerable discussion and differences of opinion about the end results. Most surgeons record later relapse of symptoms in between 25 and 75 per cent. of cases. R. W. Moore and R. Hendricks found in a follow-up of ulcer perforations that only about a third of the duodenal cases and a quarter of the gastric cases remained symptom free, and 6 per cent. suffered a recurrent perforation.§

Needless to say the patient who has undergone simple suture of a perforation of a peptic ulcer should be kept under observation and if recurrent symptoms occur further surgery should be considered.

Hæmorrhage from Peptic Ulcer

In all parts of the world there is considerable controversy as to the part which surgery should play in the treatment of bleeding peptic ulcer On the one hand are those who having only called in a surgeon to late cases find operation associated with a very high mortality and so abandon surgery altogether in the treatment of these emergencies. On the other hand there are those who treat all cases conservatively at first, but who use surgical intervention in selected cases at an earlier stage. that is, if bleeding is continuing or is repeated, then a surgeon is called in The trouble here is that some patients will die while the physician is making up his mind, and many are in bad general condition for surgery by the time it has been decided that operation is advisable At the opposite extreme are those who believe in immediate operation‖ for all patients with severe bleeding who have a history of chronic peptic ulcer, or in the absence of such a history if the hæmorrhage is repeated Against this plan is the heavy call made on highly trained gastric surgeons, and the difficulty in finding the necessary surgical team in more remote areas.

No final conclusion has been made on these points but undoubtedly the decision as to the best line of treatment must depend to some extent on the surgical facilities available.

Statistics give little help because in most series widely different types of cases treated by different physicians and surgeons are compared Earlier in this century most cases in this country were

* [illegible] Brit. Med. J., 1944, ii, 617 and 655

[illegible] xxiii, 442

treated medically, but as a result of the advocacy of Gordon-Taylor and his impressive results surgery has since attained a prominent place in the treatment.

The severity of the bleeding is to be judged by the amount of blood, or particularly of clots, vomited, the amount of melæna, and the degree of the hæmorrhagic shock as shown by colour and the variation in pulse rate and blood pressure. Blood hæmoglobin and red cell estimations are of value particularly in the more prolonged forms of bleeding. Estimation of blood volume or hæmatocrit gives more information in the more severe hæmorrhages.

Operative technique.—When it has been decided to operate the writer uses local anæsthesia for gravely ill patients, but good general anæsthesia by an expert has some advantages. If not already in use a blood transfusion should be set up as soon as the decision to operate is made and should be continued throughout the operation and afterwards. The abdomen is opened by a high midline incision, though if it is known beforehand that a deeply placed chronic duodenal ulcer is present, then a high transverse incision extended well to the right is useful in obese patients. Extreme vascularity of the parietes will give rise to suspicion of portal hypertension, or an abnormality in blood clotting.

The stomach and duodenum are examined visually and by palpation for the presence of ulcer or ulcer scar, tumour or polypus. The liver is examined for signs of cirrhosis and the size of the spleen is noted. If the colon and small bowel are full of dark blood, it is proof of continued bleeding. In negative cases careful examination of the other viscera, pancreas, gall bladder, etc., must be carried out.

In some cases of subacute ulceration the crater may be impalpable but the bristle-like thickened vessel in its base may be felt. If nothing to account for the bleeding is revealed then the posterior wall of the stomach and duodenum, the second part of the duodenum and œsophageal hiatus are examined, and then the upper jejunum. If the examination is still negative a gastrotomy may be performed, though this rarely gives much further information except that it may reveal multiple small erosions.

Gastric ulcer.—If a chronic gastric ulcer is present it is usually simplest and best to perform a partial gastrectomy. If the ulcer is massive and deeply penetrating and the patient's condition too grave for gastrectomy then the stomach is separated from the liver or pancreas—whichever organ is invaded—and the ulcer edges in the stomach trimmed. The resulting opening in the stomach is firmly closed with running sutures, which are deep enough to include the whole of the ulcer edge, and so compress any bleeding-point.

Other methods of dealing with the ulcer must be kept in mind for cases in which gastrectomy is not feasible. Local excision of the ulcer, ligature of the vessels entering the ulcer base, or ligature of the bleeding

vessel in the ulcer base are at times of value, particularly in cases of bleeding gastro-jejunal ulcer.

Duodenal ulcer.—If a duodenal ulcer is present the most certain method of arresting bleeding is also to carry out a partial gastrectomy. If the patient is very ill, or the surgeon not very experienced in dealing with difficult penetrating duodenal ulcers, then a longitudinal incision is made in the duodenum, the ulcer exposed and its edges firmly sutured together with wide and deep silk sutures. The incision is then closed and a gastro-jejunostomy carried out. This is not so certain a method as gastrectomy because an occasional case, perhaps one in ten, will bleed again.

As the hæmorrhage has often temporarily ceased at the time of operation, an exclusion gastrectomy, that is a Polya type of gastrectomy with prepyloric section and closure of the antrum is justifiable in difficult duodenal cases. In view of the likelihood of the development of stomal ulceration in such cases, the pyloric antrum should be excised at a second operation six to twelve weeks later.

Difficulty arises in the decision as to what should be done if no ulceration or other abnormality is found, even on gastrotomy. In such cases the writer has on few occasions contented himself with tying the right and left gastric and the right and left gastro-epiploic arteries, and all survived, though one case of erosive gastritis required a gastrectomy ten days later. Finsterer recommends partial gastrectomy as a routine in such cases, and the writer now agrees with him. The point in favour of the latter is the frequency with which undetected acute gastric ulcer or gastric erosions may be found in the excised specimen.

Post-operative course.—Recovery tends to be more stormy than after elective gastrectomy, the patient having less resistance to peritoneal, lung and wound infection. The general principles of after-care are much the same as after the elective operations but the patient will require particularly watchful management. The blood hæmoglobin should be brought up to 70 per cent. if possible by transfusion, and antibiotics to combat or prevent infection must be prolonged to the fullest extent.

Results.—In considering the results of surgery for hæmatemesis, it must be borne in mind that the operative mortality depends on the type of case selected for surgery. If only the severe cases are handed to the surgeon and at a late stage a high operative mortality must be expected, but nevertheless this late intervention may result in saving of life, and in judging the value of surgery, the *overall* mortality of hæmatemesis and melæna rather than the *operative* mortality must be considered. Chiesman* found that with hæmorrhage recurring within 24 hours the mortality without operation was 74 per cent., and Avery Jones† in a similar series found a mortality of 78 per cent., therefore if such cases are operated upon with a mortality lower than this it means a saving of life

* W. E. Chiesman *Lancet*, 1932 ii. 722.

† F. A. Jones *Brit Med J.* 1947 ii 441 447

Age plays an important part. The writer* had a consecutive series of 501 cases of ulcer-hæmorrhage with only one death in patients aged forty and under. Surgery was occasionally required in this group and the one fatality was in a patient who refused operation.

The mortality from bleeding gastric ulcer is higher, about twice that of bleeding from duodenal ulceration.

The mortality of hæmorrhage from gastro-duodenal ulcer has diminished of late years and in a series of 183 cases in 1948–1949, largely treated surgically, the writer† had an overall mortality of 7 per cent. and, in 1947, Avery Jones reported a larger series mainly treated medically with an overall mortality of 7·8 per cent.

" Hour-glass " Stomach

This condition of cicatricial narrowing of the stomach may be congenital but so much more likely to be the result of ulceration—usually somewhat diffuse or multiple ulceration high up on the lesser curve. It is commoner in women.

The condition is often of mild degree and is not infrequently found in aged persons associated with slight symptoms. If, however, ulcer symptoms or symptoms of obstruction are severe, or if symptoms relapse after medical treatment, then surgery is advisable.

In the majority of cases a partial gastrectomy, as for ulcer, should be carried out. As the recurrent ulcer rate after gastrectomy for this condition is extremely low, the operation may be fashioned to conserve as much stomach as possible, up to about a third of the organ. Operations on the stenosis such as local plastic procedures, gastro-gastrostomy, gastro-jejunal anastomosis to the upper pouch, may be of value in very starved, senile or fragile patients but are rarely indicated nowadays.

If such lesser operations fail then gastrectomy may still be carried out as a further intervention.

LATE COMPLICATIONS OF OPERATIONS ON THE STOMACH AND DUODENUM

Gastro-jejunal Ulceration

In any operation in which the stomach is anastomosed to the duodenum or jejunum, ulceration at or near the site of anastomosis may occur (*see* pp. 796–798).

It is almost always true to say that the majority of patients who develop periodic post-prandial pain, relieved by alkalies, or who suffer from hæmatemesis after a gastro-jejunal anastomosis, have developed gastro-jejunal ulceration. Some ulcers show their presence by perforation. The presence of the ulcer is not always easy to prove, even with the combined use of X-rays and gastroscopy.

* N. C. Tanner, *Proc. R. Soc. Med.*, 1950, xliii, 145.
† N. C. Tanner and A. M. Desmond, *Overseas Post. Grad. Med. J.*, 1950, iv, 351.

Tenderness over the site of the stoma, and the presence of occult blood in the fæces are valuable pointers to stomal ulceration.

Indications for operation.—The condition is very prone to relapse even after the most careful medical treatment and surgery is indicated in the majority of cases.

Operative technique.—As the basic cause of the recurrence is gastric hyperacidity, some method of reducing it must be utilized. The methods available are vagotomy or very high gastrectomy, or both.

Partial gastrectomy.—This is the most well tried and satisfactory method of dealing with these difficult cases, particularly if arising after gastro-jejunostomy. If one of the vertical incisions near the midline in the upper abdomen has been made it is re-opened. The transverse incision is not so suitable. There are often a number of adhesions, and it will usually be wiser to commence by opening the peritoneum in the upper part of the wound as one is less likely to encounter adhesions over the liver and, even if it is adherent, a small accidental incision into that organ has no serious consequences. When the peritoneum has been opened all adhesions must be carefully dealt with. The first step is to demonstrate the topographical anatomy which is much obscured. No attempt whatever must be made to deal with the lesion until the viscera have been mobilized and the anatomy restored When the omentum, colon and anterior surface of the stomach have been entirely freed from the abdominal wall and the liver, the parts should be explored Until a thorough exposure has been obtained no decision as to a plan of operation can be made. Gastro-jejunal ulceration is made manifest either by a hard indurated mass, a crater, scar, speckling or obvious signs of inflammation in the neighbourhood of the anastomosis.

When the parts have been identified and mobilized the transverse colon is turned upwards and the mesocolon carefully dissected off the old anastomosis. This is a slow and tedious procedure, for the mesocolic arterial arch must not be injured or the transverse colon may be devitalized. When the mesocolon is completely freed, the anastomosis may be pushed up through it The gastro-colic omentum is now divided between ligatures down to the duodenum, and the right gastro-epiploic and right gastric pedicles are also divided in the manner usual with a partial gastrectomy. The duodenum is similarly divided between clamps and its distal end is closed and embedded, except when it is desired to make a Billroth I reconstruction. The stomach is now turned upwards and non-crushing clamps are placed on the stomach and on the jejunum on either side of the gastro-jejunostomy. After carefully packing off the surrounding wound, the gastro-jejunostomy is undone by cutting through the exact line of anastomosis with a sharp scalpel This line will be found to be practically avascular. The opening in the stomach is temporarily sutured or a pack is clamped on to it with Rutherford Morison catch forceps. The jejunum is examined to ensure that there is no gross

ulceration at its edge or in its lumen and no stenosis present. If it is satisfactory the jejunum is repaired by closing the opening in the jejunum transversely, in two layers, which leaves an ample lumen. If there is severe jejunal ulceration or damage, then instead of cutting through the anastomosis as described, after dividing the mesentery a short length of jejunum is resected and left attached to the stomach and an end-to-end restoration of the jejunum is made. When the jejunum is repaired or resected the stomach is turned up and to the left, the left gastric artery is tied and divided and a high partial gastrectomy completed as previously described. The opening in the mesocolon may be used again for retrocolic anastomosis or better still it may be closed and an antecolic anastomosis employed.

A Billroth I anastomosis is not usually desirable in these cases because so often the primary condition has been duodenal ulceration and the duodenum may be scarred and deformed and not suitable for the direct anastomosis.

It is generally unwise to use the old opening in the jejunum for the new gastro-jejunal junction, but on occasions this may be done with success.

As an alternative in frail patients the gastro-jejunal anastomosis may be undone, the stomach and jejunum closed and a pyloroplasty performed with which a vagotomy may be combined.

Vagotomy.—For ten or more years this method must remain under trial. It appears to be suitable for dealing with stomal ulcer after gastrectomy or gastro-jejunostomy, so long as the previous operation has no technical fault. If the anastomosis is functioning poorly or there is severe ulcer penetration or deformity it is best to convert a gastro-jejunostomy into a gastrectomy, or if a gastrectomy has already been carried out then a higher resection will be necessary combined with vagotomy.

The parietal incision may then be closed in layers or there may be so much scar tissue that through and through interrupted sutures are better.

Gastro-colic Fistula following Non-malignant Ulceration

If this complication develops, severe deterioration occurs, because much of the gastric content passes directly into the colon, resulting in post-prandial diarrhœa and rectal excoriation. The diarrhœa is made worse by jejunitis resulting from the passage of some of the fæcal material into the small bowel. As a result of the loss of fluid and food, dehydration, starvation and vitamin deficiencies may be severe. Foul eructations and fæcal vomiting may add to the patient's distress. There may be varying degrees of colonic stenosis.

Treatment.—There are several ways of approaching this problem. The writer's preference is as follows. The patient is given intravenous infusions of saline, glucose and blood, and vitamin injections. Then

a colostomy, with a good spur, is made in the ascending colon, the hepatic flexure or at the extreme right of the transverse colon. This can be done under local anæsthesia. (General anæsthesia should be avoided at this stage because of the great infectivity of the gastric contents, and the dangers of their inhalation under general anæsthesia.)

A cæcostomy is preferred to colostomy by some surgeons, particularly as it is usually very easy to close.

When the colostomy commences to function fæcal vomiting ceases, and in addition the diarrhœa often lessens and the patient's condition improves. This is in part due to relief of the fæcal jejunitis and it is also possible that the inactive transverse colon contracts, contains less chyme and leads to narrowing of the fistula.

When it is judged that the patient has gained the maximum benefit from the colostomy, usually after two to three weeks, a second operation is performed. The original upper abdominal incision is re-opened and, after careful dissection as described under "gastro-jejunal ulcer", the attachment of the transverse colon to the anastomotic area is identified. After this is freed by sharp dissection, the openings into the colon and into the gastro-jejunal stoma are cleared and defined. The opening in the colon may be closed satisfactorily in two layers, but if the large bowel lumen is constricted, a longitudinal incision is made in the length of the bowel from either side of the fistulous opening, and the enlarged opening is then stitched transversely after the principle of pyloroplasty, thus leaving an adequate lumen. If there is ulceration near the mesentery, or severe colonic scarring, removal of a short segment of transverse colon with end-to-end anastomosis is advisable. Soiling does not occur, for the transverse colon has been defunctioned and then "lavaged" with gastric juice. If the patient is in reasonable condition the gastro-jejunostomy is undone and a high gastrectomy performed as has been described under "Gastro-jejunal Ulcer". On the other hand, if the patient is too ill for this major procedure, the opening in the gastro-jejunal stoma should simply be closed, leaving the question of gastrectomy for a subsequent occasion.

All being well the colostomy may be closed (*see* p 1038) three or four weeks later. In milder cases a preliminary colostomy is unnecessary, and is replaced by careful gastric lavage and the administration of intestinal antiseptics—e.g sulphathalidine, by mouth. Some surgeons prefer this form of preparation in all cases.

Results

If the connexion between colon and gastro-jejunostomy is merely freed, and the holes repaired, gastro-jejunal ulceration may continue and a new gastro-colic fistula may arise After gastrectomy the late results are far superior. The mortality of this operation depends on the care taken in preparing the patient as well as the care expended during the operation and has much diminished of late years

Retrograde Jejuno-gastric Intussusception

At periods between a few days to several years after gastro-jejunostomy intussusception of the afferent loop into the stomach may occur, or retrograde intussusception of the efferent loop, or both. It may also occur after gastrectomy, but either variety is a rarity.

The condition may present with symptoms of intestinal obstruction or with hæmatemesis,* or as a combination of hæmatemesis with epigastric colic. The condition must always be suspected where severe pain accompanies hæmatemesis, in a patient who has had a gastric operation. Visible gastric peristalsis may be present, and radiological examination of a barium meal will show a large filling defect in the stomach.

Operation is indicated as soon as the condition is diagnosed. The old incision is re-opened and the diagnosis confirmed. A mass will be felt in the stomach, and it is usually possible by squeezing this mass to reduce the intussusception. If this fails an attempt at reduction may be made after opening the stomach wall. Sometimes it is necessary to resect the strangulated bowel.

Prevention of recurrence may be attempted by suturing the afferent and efferent loops together or by converting the operation into a Billroth I gastrectomy, though this should not be done as an emergency measure.

Post-cibal Disturbances

It is unfortunate that after gastrectomy in a certain percentage of cases (about 7 per cent. in the writer's series), unpleasant symptoms may be experienced after eating. These symptoms include a feeling of excessive warmth, sweating, dizziness, epigastric discomfort and fatigue Sometimes " black-outs " or temporary unconsciousness may occur. Cases presenting such symptoms are reported from all parts of the world, and may occur after every form of gastrectomy. The causation is obscure. They have been attributed to hyperglycæmia, hypoglycæmia, rapid blood sugar variations, vagal stimulation, over-distension of the gastric remnant or of the jejunum, traction on the œsophagus, etc They are not relieved by vagotomy. Fortunately the symptoms, which usually commence shortly after the patient leaves hospital, tend to diminish or disappear with time.

When possible a short holiday should be given, and the patient told to recline for 20–30 minutes after meals or as soon as the symptoms arise. He should be persuaded to eat slowly but well, particularly protein and fatty foods, in order to achieve a stable blood sugar. The meals should be dry, and milk and other drinks should be taken between meals. In severe cases, which persist for over a year, particularly where there is associated bilious vomiting, further surgery may be indicated in those patients on whom a gastro-jejunal anastomosis was made after gastrectomy. Short circuiting of the afferent and efferent loops gives relief in some cases, but the procedure found

* A. W. Adams, *Brit Med J*, 1935, i, 388

more effective by the writer is to dismantle the gastro-jejunal stoma, repair the jejunum, and after careful mobilization of both stomach stump and second part of the duodenum, to anastomose the stomach to duodenum, restoring the natural channel.

Vagotomy "Side Effects"

This term has been adopted for symptoms which may occur after vagotomy. The chief complaints are of a "bloated" feeling after eating, eructations which may be of foul sulphurous smelling gas, occasional cramping pains in the abdomen, and diarrhœa. *They no* doubt result in part from the combination of gastric retention with hypochlorhydria. They tend to diminish with time—possibly when gastric tone and peristalsis become more normal, as they do six to twelve months after operation. A 12-hour fast, or gastric lavage, followed by a course of small dry meals gives some relief. The diarrhœa is usually an early morning looseness, but it may be severe. The latter is usually relieved by giving a combination of acid. hydrochlor. dil. (dr. ii four hourly) and sulphasuxidine or one of the allied non-absorbable sulphonamide intestinal antiseptics. If symptoms of discomfort and belching persist after six months, and X-ray shows severe delay in gastric emptying, then gastro-jejunostomy, pyloroplasty or partial gastrectomy is indicated.

The best means of prevention of these side effects is by always *combining the operation with pyloroplasty, gastro-jejunostomy or* partial gastrectomy.

Anæmia

This may occur after gastrectomy or after gastro-jejunostomy. It is almost always of the iron deficiency type and may result in part from loss of gastric internal secretion and of digestive juices and in part from a post-operative gastritis It is usually relieved by the oral administration of ferrous iron, and iron-containing foods, which should be taken regularly.

In rare cases, particularly where total gastrectomy has been carried out, a macrocytic anæmia may develop. This will require treatment with liver extract and lifelong supervision by a physician

OPERATIONS FOR GASTRIC CARCINOMA

Indications for operation.—Carcinoma of the stomach is a relatively common disease and in England accounts for about a quarter of the total number of deaths from cancer. The only hope of cure at present is from surgical removal of the tumour and its extensions. It is an unfortunate fact, that of all the cases diagnosed, only a small proportion are suitable for resection and few survive five years or more after operation Of 1,405 cases of gastric cancer treated in London in 1938–9, 17·3 per cent. were dealt with by gastric resection, and of the survivors about one-fifth lived five years.

Although without operation a patient may live up to a year or 18

months, this period is often one of profound misery and discomfort, and so an operation, even with a high immediate mortality and a low cure rate, is justifiable. Even when there is no great chance of cure, gastrectomy as a palliative measure relieves vomiting and hæmorrhages, diminishes pain and gives an added period of comfortable and useful life. Though this period is often short, it may be prolonged to two or three years or longer, and so from the patient's point of view palliative resections are well worth while. Every patient should be given the chance which operation alone affords, unless there is positive evidence from the presence of secondary deposits that the disease is too advanced to make surgery of any avail. Palliative resection is sometimes justifiable even where such deposits, e.g. in the liver, are present

In order to give the best chance of survival the resection must be wide, and must include the adjacent lymphatic fields. As many of the patients are aged, the disease being commonest between the ages of 50 and 70 years, and may be starved and anæmic, the operative mortality is high—it was 32·9 per cent. in the series mentioned above.* Fortunately the position is somewhat improved since then. There is an increasing awareness of the need for early diagnosis. Gastroscopy and improved and more frequent radiological examinations have slightly increased the early diagnosis rate. The operability rate is increased by the fact that carcinoma of the upper stomach has come into the field of radical surgery and operative mortality has diminished for resection of all parts of the stomach.

Preparation for operation.—The patient should be in hospital or nursing home for a minimum of three to four days' bed rest prior to operation and often much longer is needed in debilitated subjects A high protein diet is given and any vitamin deficiency corrected. If anæmic, iron is given by mouth, and also blood transfusions. If enough fluid cannot be taken by mouth dehydration is dealt with by daily intravenous or rectal infusions If there is gastric retention the stomach is emptied and washed out with saline twice daily and this often increases the amount that can be absorbed by mouth feeding while greatly adding to the comfort of the patient

Breathing exercises, etc , are given as described under " Prevention of Chest Complications " and " Early Ambulation," p 830.

Operative technique.—The operation to be performed will depend on the position in the stomach at which the growth is situated, but as Grey Turner so constantly emphasized, the object is always the same, removal of the growth together with a wide area of tissue in the path of probable malignant invasion. If the tumour is localized near the pylorus, radical partial gastrectomy removing the lower three-quarters of the stomach with all the surrounding cellular tissue and lymph nodes will suffice. If the growth is higher, then a margin of some 6 cm of apparently healthy tissue above the growth

* W. L. Harnett, *Brit J. Surg*, 1947, xxxiv, 379.

should be excised, and this means that a total or almost total gastrectomy is required for most mid-gastric tumours, while part of the œsophagus will have to be removed if the growth involves the upper stomach or cardia. It must be borne in mind, however, that once the upper level of transection is in the œsophagus there is a sharp rise in the operative mortality rate above that obtained when even a *fringe of gastric mucosa is left.*

Radical gastrectomy for carcinoma of the lower stomach.—This entails removal of the lower three-quarters to four-fifths of the stomach, with an inch or more of duodenum, and the adjacent mesenteries, omenta and lymphatic fields. Though the general plan of technique is very similar it differs from the operations for peptic ulcer in that the stomach must be divided well above the edge of the tumour, and that the lymphatic fields must be widely removed.

A long and high right paramedian or mid-line incision is made and the exposure may be improved by dividing the ligamentum teres near the liver. A careful examination of the growth and of the whole peritoneal cavity is made, but the growth should be palpated very gently to minimize the chance of disseminating cancer cells. The pelvis, paracolic gutters and peritoneum generally are palpated and any suspicious nodule inspected. Cysts and small fibromata of the liver capsule feel like metastases but are usually different in colour and not umbilicated. The adjacent organs and the under surface of the mesocolon are examined for invasion by growth, and the lesser sac opened to examine the posterior surface of the stomach

The extent of glandular invasion is assessed, and if hard glands are felt in situations where they cannot be included in the resection, for example, in the mesentery of small intestine or in the portal fissure, a gland may be sent for histological examination by the rapid smear or frozen section technique

Locally invasive types of tumour which infiltrate surrounding organs such as the liver, pancreas, spleen, colon, mesocolon, small bowel or abdominal wall, are not necessarily hopeless, for the whole or part of the invaded structure may be removed en bloc with the stomach. Perhaps one of *the commonest structures to be involved* is the mesocolon, and this may be removed freely, with if necessary the middle colic artery. So long as the marginal artery is intact the bowel usually remains viable After any such mesocolic resection the transverse colon must be inspected at the end of the operation, and if it shows signs of loss of blood supply, it must be resected and either repaired by anastomosis or the open ends brought out of the incision *for subsequent management*

The difference in technique between resection for carcinoma and that for simple ulcer as described previously is as follows. Instead of freeing the greater curve by dividing the epiploic branches of the gastro-epiploic arch, the great omentum is lifted upwards and separated from the colon by dividing the avascular attachment between it and the colon A few small vessels may be encountered

but any oozing can usually be arrested by placing a hot pack on the colon. The subpyloric group of glands must be freed with the stomach by dividing the gastro-duodenal artery just as it leaves the neck of the pancreas and the glands are then stripped away from the pancreas and left attached to the pylorus. When ligating the right gastric artery any gland in relationship to it must be removed with the stomach. The duodenum should be divided at least 2·5 cm. from the pylorus, and at least 3 cm. distal to the edge of the growth. The gastro-hepatic ligament is divided flush with the liver and up as high as the œsophagus. The left gastric artery is then exposed by dividing the peritoneum over it, just above the pancreas. The glands and tissues near its origin and round the cœliac artery are gently swabbed towards the stomach and the left gastric vein and artery are then tied separately and divided. Next the glandular and fatty tissue round the œsophagus is freed and drawn downwards. The fatty tissue, glands and vessels passing between the left gastric and the œsophageal arteries to the right of the œsophagus, that is at the upper level of the gastro-hepatic omentum, are divided and the upper end ligatured. The tissues and glands round the œsophagus and the tissues adjacent to the lesser curve are drawn downwards, dividing and ligaturing one by one the vessels which pass from it to enter the lesser curve of the stomach, leaving the lesser curve bared, until the site of gastric transection is reached. This level must always be very high, even in pyloric growths, and preferably, as suggested, at least 6 cm. above the upper level of the obvious tumour. The left gastro-epiploic artery and two or three vasa brevia are divided well away from the stomach until the transection level on the greater curve is reached. A clamp is then placed across the stomach at this level. The gastrectomy then proceeds as described under the Polya method, either ante- or retro-colic. If the growth is not too near the pylorus and the duodenum is well mobilized, the Billroth I method may be used. If the above method has been followed it will be found that the whole greater and lesser omenta, the paracardial, subpyloric and left gastric glands are with the specimen. If the removal appears to have been inadequate at any point, more tissue thereabout should be removed before proceeding to the final anastomosis.

Post-operative treatment.—This will follow the lines laid down for gastrectomy for peptic ulceration, but shock may be more in evidence, and not uncommonly some degree of generalized intestinal ileus with abdominal distension may develop for a few days. The latter is probably associated with the vagal division which results from the extensive tissue removal Diarrhœa sometimes occurs. Blood and saline transfusions and more prolonged gastric decompression with an indwelling gastric catheter are usually required.

Upper partial gastrectomy and total gastrectomy.—As already mentioned, in order to transect wide of any carcinoma in the stomach wall, it is advisable to transect some 6 cm. above the upper edge of

the infiltrative types of growth. This means that in the majority of upper and some mid gastric cancers the line of transection will be through the œsophagus, and as the cardia provides no barrier to the extension of tumour cells, a length of œsophagus may also have to be removed. This is not very difficult by the abdominal route in slender patients, *provided that the viscera are lax, the growth mobile* and that the transection is at the very lowest level of the œsophagus. It is, however, easier, and safer, judging from the writer's series, to perform this operation by an abdomino-thoracic approach, for œsophageal suturing can then be performed with greater ease and consequently with greater security.

Abdomino-thoracic gastrectomy. **The incision.**—The patient is placed *on the operating table and fixed on his or her right side, at right angles*

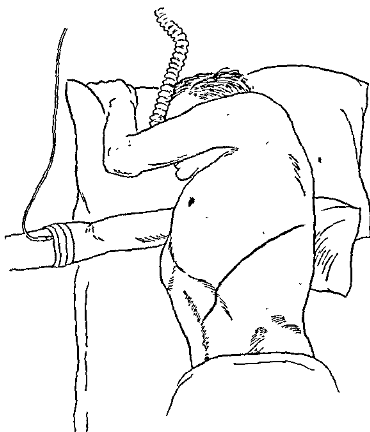


Fig. 354.—Site of incision for abdomino-thoracic approach to cardia and lower œsophagus.

to it. *If the operating table has a mechanism* for tilting laterally, it is convenient to give a slight dorsal tilt at the beginning and a slight ventral tilt towards the latter part of the operation After placing towels in position a transverse incision is made, starting at a point midway between umbilicus and xiphisternum and passing laterally to the left costal margin This is deepened in the same line until the peritoneum is reached and this is then widely opened. The left hand of the operator (who stands to the left of the patient) is inserted and

the growth and its extensions and the abdominal viscera are palpated.

If the growth appears to be operable, then with the left hand, which is still in the abdomen, the eighth rib is identified. In the line of this rib the transverse incision is continued obliquely over the costal margin as far as the lateral border of the erector spinæ muscle (Fig. 354). The incision is deepened through the serratus anterior, latissimus dorsi and trapezius muscles to expose the whole of the eighth rib, which is then removed. A short length of the costal margin may also be excised to prevent overriding after closure of the wound. During this part of the operation great attention is paid to careful hæmostasis, and a blood drip transfusion is started. If preferred, an intercostal incision may be made instead of the rib resection.

The pleural cavity is carefully opened in the anterior part of the rib bed—that is at the point in the costo-phrenic sulcus which is just below the lung, and where the lung consequently runs no risk of damage. Once the pleural cavity has been reached it is then widely opened and a rib spreader inserted and opened. The Finochietto model is very suitable for the purpose. An incision is made through the diaphragm from its periphery at the rib margin to the œsophageal hiatus, taking care to ligate any vessels in this muscle and also the inferior phrenic vessels which lie close to the hiatus (Fig. 356). The abdominal and pleural cavities are thus thrown into one The ligamentum latum pulmonale is now divided and the lung retracted upwards. A vertical incision is made in the mediastinal pleura, anterior to the aorta, to expose the lower œsophagus. The phrenic nerve may be crushed or injected with local anæsthetic to produce temporary diaphragmatic inactivity.



Fig. 355.—Scar of parietal incision after abdomino-thoracic resection of upper stomach and lower œsophagus.

The resection.—The growth is re-examined and the levels of œsophageal and gastric division determined. If the tumour is mid-gastric it is wiser to remove the whole stomach, but if confined to the cardia region and the subpyloric glands are not enlarged or hard, then the pyloric part of the stomach may be spared

The resection is commenced as described for carcinoma of the lower stomach, by freeing the great omentum from the transverse colon. The spleen is then lifted forwards and the lieno-renal ligament divided to expose the splenic artery and vein, which are tied and divided close to the pancreatic tail The stomach and spleen are lifted upwards and the stomach freed by sharp dissection from the œsophageal hiatus—

though if the latter is traversed by growth, part of the musculature round the hiatus will require to be removed with the growth.

The stomach and spleen are lifted forwards and to the right exposing the peritoneum, fatty and glandular tissues round the left gastric vessels All the tissue round the vessels is isolated, divided and separated towards the stomach to be removed with the viscus. The

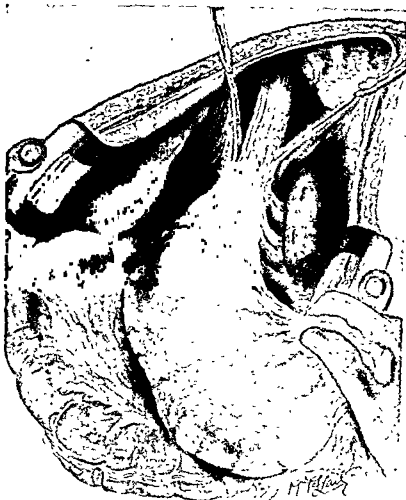


Fig. 356.—Abdomino-thoracic approach to carcinoma of cardia The diaphragm has been divided up to the œsophageal hiatus.

left gastric artery and vein thus bared and isolated are tied independently and divided.

With scissors the gastro-hepatic omentum is divided close to the liver, leaving it attached to the stomach. The small vessels in the ligament must be ligated bearing in mind the possible presence of an accessory or abnormal hepatic artery.

If a *total gastrectomy* has been decided upon the subpyloric glands are dissected free, the right gastric and right gastro-epiploic vessels divided, and the duodenum is transected and closed as previously described for carcinoma of the lower stomach

The stomach is then turned upwards, the œsophagus divided between clamps 4–6 cm. above the growth and the stomach removed.

There are several ways of restoring alimentary continuity after total gastrectomy. In subjects with lax viscera it is often easy to anastomose œsophagus and duodenal stump end-to-end, as Grey Turner pointed out many years ago.

The standard method of anastomosis is to perform end-in-side anastomosis of œsophagus to jejunum. This is sometimes difficult owing to shortness of the meso-jejunum, though quite satisfactory in the more restricted abdominal resections (Fig. 364c). Fig. 357 shows some methods of restoring continuity after total gastrectomy.

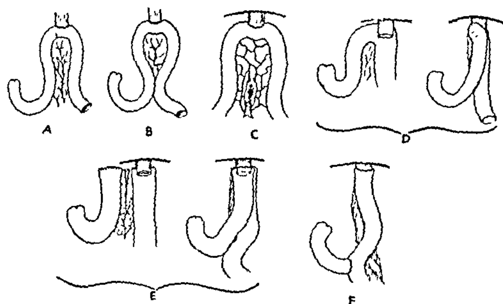


Fig. 357.—Reconstruction after total gastrectomy.

A, End in-side œsophago-jejunostomy B, The same with the afferent and efferent loops anastomosed C, Sweet's method of elongating the mesentery D, Roscoe Graham's method of anastomosis E, Lefevre's method often practised on the Continent F, Roux' method of end-to-end œsophago-jejunostomy.

The writer's preference is for end-to-end œsophago-jejunostomy ("Roux-en-Y" anastomosis). The jejunum is transected about 18 inches beyond the duodeno-jejunal flexure. The mesentery is divided and one main branch of the superior mesenteric artery entering the distal limb is carefully tied and divided. Care is taken to maintain the integrity of the vascular arches near the bowel. Occasionally a second main artery must be divided in order to mobilize the jejunum sufficiently to bring it up to the œsophagus (Fig. 358). The proximal cut jejunal end is anastomosed to the distal limb, end-to-side, about two feet farther down the bowel The distal cut end is now drawn up through an opening made in the mesocolon and approximated to the œsophagus. Packs are placed under and round the adjacent jejunum and œsophagus. Bowel clamps are better avoided. An end-to-end anastomosis is made, using an outer continuous catgut

suture, and inner suture of fine interrupted silk sutures. About 14 of the latter sutures are needed and it is most important that each of the inner or "all the coats" sutures takes a good "bite" of œsophageal mucosa which is the only strong structure in its wall. If the mucosa is allowed to slip away and is not included in the suture



[illegible] for end to end œsophago-jejunal anasto- [illegible] noved. [illegible] tran- sected jejunum is mobilized sufficiently to pass through it to reach the œsophagus without tension.

stenosis will develop. When the anastomosis is completed the œsophagus will be seen to be somewhat telescoped into the wider jejunum (Fig. 359) Any weak point may be reinforced by interrupted silk sutures.

The mesocolic opening is then closed around the inlying jejunum with a few sutures Any slits or apertures left adjacent to the

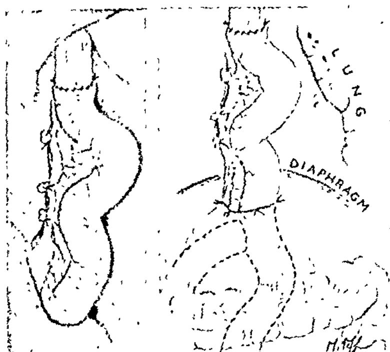


Fig. 359.—Total gastrectomy with end-to-end anastomosis of œsophagus to a Roux-en-Y loop of jejunum.

jejunum just below the mesocolon, through which small intestine might herniate, are closed, taking care not to perforate the mesenteric vessels with the needle.

(For completion of operation, see "Repair of diaphragm and parietes" at p. 854.)

Upper partial gastric resection.—If it is decided to retain the pyloric part of the stomach, the gastro-epiploic arch, and the arch of vessels on the lesser curve are tied and divided. The stomach is then transected between clamps at about the junction of the body with the pyloric antrum. The stomach and œsophagus are lifted upwards and the œsophagus divided between fine anastomosis (e.g. Lang Stevenson) clamps. The segment of stomach and œsophagus is removed and packs are then placed round the divided ends of



Fig. 360.—X-ray of opaque meal following total gastrectomy and end-to-end œsophago-jejunostomy.

œsophagus and pyloric antrum which are to be anastomosed. The classical method of anastomosis is to close the cut end of the pyloric antrum and anastomose the œsophagus to a rounded opening made in its anterior wall. A method of direct anastomosis more satisfactory, and found safe by the writer, is as follows:—*The extremities of the* cut end of the pyloric antrum are closed with an "all the coats"

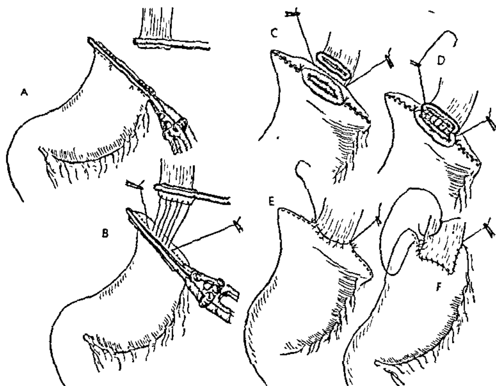


Fig. 361.

stitch until the diameter of the open middle part corresponds in size with that of the œsophageal lumen (Fig. 361A) A posterior continuous stitch of catgut is made between the adjacent posterior surfaces of œsophagus and stomach, passing through the musculature of the œsophagus and the seromuscular coat of the stomach (Fig. 361 B and C). "All the coats" sutures, using interrupted fine silk or linen, are now used to unite anterior and posterior cut ends of the œsophagus to the central open part of the divided stomach, again using about 14 stitches, and taking great care to include the œsophageal mucosa (Fig 361 D and E). When this is completed the posterior continuous catgut suture is continued round in such a way as to fix the closed extremities of the cut end of the stomach against the side of the œsophagus, and to unite the anterior muscular and seromuscular coats of œsophagus and stomach respectively (Fig. 361F). A few interrupted silk sutures may be added to make the anastomosis quite secure It may help very much to mobilize the duodenum as already described.

Repair of diaphragm and parietes.—The anastomosis and adjacent mediastinum are dusted with penicillin powder In order to remove

any tension on the suture line the pyloric antrum, or jejunum, or whichever part is anastomosed to the œsophagus, is drawn up and fixed with a few interrupted stitches of fine silk to the cut edge of the mediastinal pleura, or to the pleura to the left of the aorta (Fig. 362).

Next the diaphragm, at the point through which jejunum or pyloric antrum will pass, is drawn downwards and with a few fine stitches fixed in this position to the jejunum or pylorus. By fixing it so, no

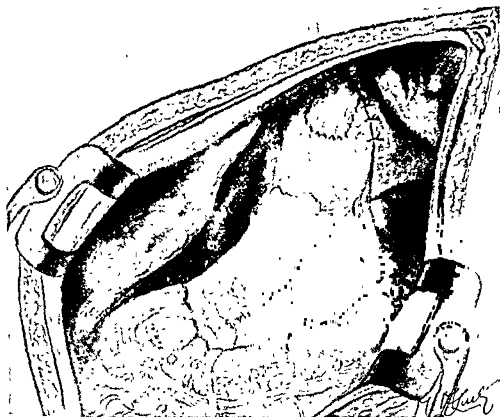


Fig. 362.—Upper partial gastrectomy by abdomino-thoracic route. Interrupted fine stitches are placed between remnant of stomach and the parietal pleura to take *tension off the anastomosis.*

depth of inspiration will be enough to cause traction on the suture line. The rest of the diaphragmatic incision is repaired with a continuous No. 1 silk suture, reinforced with a few interrupted stitches.

The wound retractor is removed and the parietal incision is closed in layers, first being peritoneum and posterior rectus sheath, next the anterior rectus sheath, rectus muscle, and external oblique muscle, and finally the skin. The thorax is closed, first by uniting the pleura and intercostal muscles, and then the divided muscles of the chest wall. If an intercostal approach has been made, stitches passed through drill holes made in the adjacent ribs may be used to draw the wound together. A pleural drain may be inserted if it appears likely that much oozing will take place. During the operation the lung will have been inflated from time to time by the anæsthetist and

this should be repeated just prior to wound closure. The skin is closed with interrupted silk or silkworm gut stitches.

Extension of growth to adjacent organs.—It has already been mentioned that invasion of the mesocolon or colon may be treated by resection of the involved tissue.

Not uncommonly the pancreas or adjacent peritoneum of the lesser sac is invaded by a carcinoma of the posterior wall of the stomach

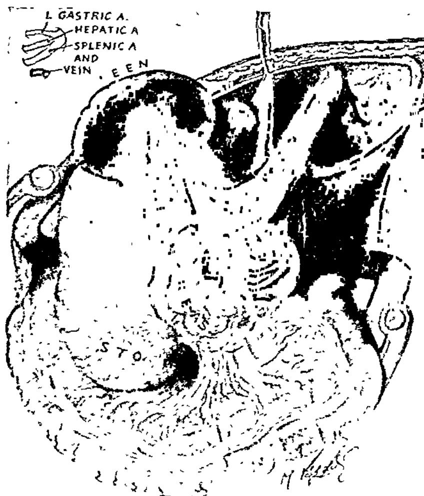


Fig. 363.—Partial resection of pancreas and posterior wall of lesser sac with upper stomach. The spleen, stomach, pancreas and posterior lesser sac peritoneum are reflected to the right until the branches of the cœliac axis are exposed

In such circumstances, provided that the extension is not widespread and the growth of the locally invasive type, the resection may be extended as follows. After mobilization of the great omentum from the colon, an incision is made in the posterior peritoneum lateral to the spleen and upper stomach. The peritoneum is reflected medially, and the dissection continued medially, in front of the kidney and adrenal, and posterior to the pancreas and the lesser sac of peritoneum When the cœliac artery is encountered, the left gastric artery and the splenic artery are carefully isolated, tied and divided (Fig 363).

The pancreas is divided at about the point where the inferior mesenteric vein joins the splenic vein. The cut surface of the pancreas is inspected and if the duct is seen, it is ligated, and the stump of the pancreas is repaired with interrupted interlocking silk mattress sutures, and then the anterior and posterior surface are united with a continuous fine silk suture. The resection is then continued as described. Much of the body and tail of the pancreas, the spleen and the posterior peritoneum of the lesser sac will be removed with the resected specimen.

Local invasion of the liver in the absence of distant metastases may

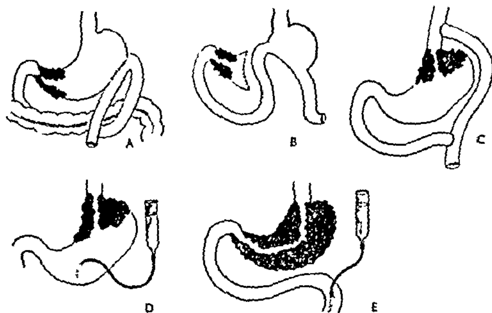


Fig. 364.—Palliative operations for gastric carcinoma.
A, Gastro-enterostomy B, Pyloric exclusion. C, Œsophago-jejunostomy. D, Gastrostomy E, Jejunostomy

be dealt with by removing the affected part *en bloc* with the primary growth (*see* Chapter XVI on the liver).

If multiple liver deposits are present (metastases) the decision as to whether palliative resection or short circuiting of the growths is justifiable must depend primarily on the discomforts or immediate dangers of the tumour, e g the degree of obstruction or amount of bleeding, and secondly on the number and size of the hepatic metastases. The presence of one or two metastases should not deter the surgeon from doing something to overcome severe dysphagia

Palliative Operations for Carcinoma of the Stomach

Palliative procedures are justifiable from the patient's point of view. The surgeon confronted at operation with a hopeless tumour may feel that nothing he can do is worth while, but a patient who submits to the anxiety and discomforts of laparotomy or thoracotomy only to find his symptoms unabated is bitterly disappointed. If he is given relief of dysphagia or of vomiting, however, he will judge the relief gained was worth the discomfort suffered.

Needless to add, a frank discussion of the position with the patient's relatives is imperative, in order that they may appreciate the surgeon's efforts and avoid disappointment later.

Gastro-enterostomy.—In the presence of a carcinomatous mass at the pyloric end of the stomach, which is irremovable, or associated with distant metastases, but at the same time causing great obstruction, much relief of the vomiting and discomfort may be obtained by the performance of a gastro-enterostomy, though the span of the patient's life may hardly be affected thereby. The operation may be a posterior or anterior anastomosis, or if the growth is very extensive, the anastomosis may be made to the greater curve high up the body, after detaching the gastro-colic ligament from it (Fig. 364, A).

Gastric exclusion.—If an irremovable carcinoma of the pyloric end of the stomach causes much pain or bleeds severely, then this operation is better. The stomach is cut across well above the tumour, the distal end is closed in two layers and the proximal end anastomosed to jejunum as in a Polya type of gastrectomy (Fig. 364, B).

Œsophago-jejunostomy.—Where the growth is at the cardiac end of the stomach, the dominant symptom is inability to swallow, and the patient is in danger of death from starvation. In such a case the alternatives are gastrostomy or short circuiting of the growth by œsophago-jejunostomy (Fig. 364, C). If the thorax is opened before inoperability is discovered, the latter plan should be considered. A loop of jejunum is mobilized as for the Roux anastomosis The loop is drawn behind the pancreas and peritoneum of the lesser sac, through a separate posterior incision in the diaphragm, into the thorax. It may then be anastomosed end-in-side to the œsophagus, after mobilization of the latter organ. This procedure gives complete relief of dysphagia, often for many months. Alternatively the œsophagus may be divided, the distal end closed and the proximal extremity anastomosed end-to-end to jejunum.

Gastrostomy.—When thoracotomy is not justified then a gastrostomy is preferable and may also be used for benign or malignant stenosis of the œsophagus (Fig 364, D). The operation may therefore be required as a temporary or as a permanent measure

Many different methods of carrying out this operation have been devised, all aim at forming a satisfactory valvular opening which will allow the passage of a catheter for feeding purposes but will prevent any leakage when the catheter is removed In the hands of most surgeons the Kader-Senn method has proved very satisfactory The operation should be done relatively early while the patient is still in fair condition After its performance he may still be allowed food by mouth, but the gastrostomy opening is present to supplement or later supplant oral feeding, as a means for disposal of saliva and to give a sense of security against starvation

A vertical incision about two inches in length is made over the middle of the upper portion of the left rectus muscle. The muscle fibres are separated and the peritoneum opened. The cardiac end of the stomach is palpated so that the downward extent of the growth can be determined. A portion of the anterior surface of the stomach well away from the edge of the growth is withdrawn from the wound and a small incision about three-eighths of an inch in length made through the seromuscular coat midway between the lesser and greater curvatures and about three inches from the pylorus. The mucosa is drawn through this incision and a small opening made into it. Through this a No. 12 (Jaques) rubber catheter with one or two extra

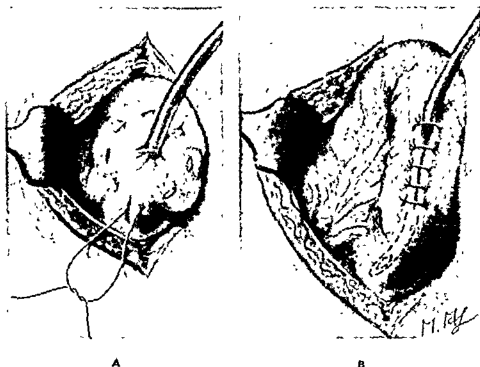


Fig. 365.—A, Kader-Seun gastrostomy. The catheter fixation stitch and the purse-string have been inserted. B, Jejunostomy by Witzel technique.

eyes made in it is passed into the cavity of the stomach for about one inch and is fixed in position by an intestinal catgut stitch which passes through all layers of the stomach and the wall of the catheter. A purse-string suture is passed through the seromuscular coats around the catheter and about half an inch in distance from it (Fig. 365A). The catheter is pushed inwards as the stitch is tied, and carries with it a cone of stomach. A second purse-string stitch is then passed half an inch external to the first, and is again tied as the catheter is invaginated. By this means a cone of stomach wall one inch in length is turned into the stomach cavity and later forms an efficient valve. A piece of great omentum is passed round the tube like a "muffler" and fixed to the stomach, and the stomach and tube are

then dropped back into the peritoneal cavity.* The rectus, anterior sheath and skin are sutured above and below the rubber catheter. If the patient is dehydrated or starved, feeding can be supplemented through this catheter as soon as he has recovered from the anæsthetic. These patients require sufficient quantities of well-balanced liquid diet. The feeds must be given slowly and at regular intervals. For psychological reasons, small quantities of food may be allowed and should be given by the mouth as long as the patient can swallow.

Jejunostomy.—A somewhat similar operation is often advocated whereby an opening is made into a high loop of jejunum. This is often satisfactory for duodenal fistula, or for carcinoma of the whole stomach, and may be used as a preliminary operation before resecting a carcinoma of the œsophagus.

A loop of jejunum is selected, about ten to twelve inches from the duodeno-jejunal flexure, and a small opening is made in it into which a No. 12 rubber catheter is sutured. An old soft catheter is preferable to a new stiff one in order to prevent jejunal perforation. The operation is completed either by the insertion of two purse-string sutures, as in gastrostomy, or by means of a longitudinal valve made by approximating the walls over the catheter by silk sutures for a distance of about one and a half inches as in the performance of a Witzel gastrostomy (Fig. 365B).

Alternatively a longitudinal incision may be made in the bowel wall down to the mucosa and the muscle allowed to retract. The catheter is laid in this sub-mucous bed and enters the bowel via an opening in the mucosa at one end of the channel. The bowel incision is closed in one or two layers over the catheter. If the lumen of the bowel appears to be narrowed by the buried catheter it is wiser to make an entero-anastomosis in order to short-circuit the loop in which it lies.

Finally the loop of bowel adjacent to the tube is lightly fixed to the under surface of the parietal wound, with the tube through a piece of omentum interposed between the bowel and parietal peritoneum.

Management of gastrostomy or jejunostomy.—Regular feeds of high calorie, protein and vitamin values are given in a sufficiently fluid state to be injected through the tube. Plain water should be run in after each feed to clear the tube, and as a fluid supplement. The catheter should be kept in for a fortnight without removal. Thereafter it may be removed for cleaning or renewal, but is kept in between these times.

When gastrostomy was only performed after the patient had become greatly dehydrated, it was a measure of considerable risk. Even to-day it carries with it a high mortality, as many of the patients have not sought advice until there is grave difficulty in swallowing. In Sir James Walton's series of 128 cases there were 20 deaths, a mortality of 17 per cent., but in his later series of 95 cases, where the operation

* G. Grey Turner, "*Injuries and Diseases of the Œsophagus*," 1946, Cassell, p. 93.

was performed earlier, the mortality had dropped to 8 per cent. In only one of these cases was there any difficulty from leakage from the gastrostomy opening.

Post-operative Treatment and Results after Operation for Gastric Cancer

The post-operative treatment of radical lower gastric resection follows the lines of the resection for simple ulcer. Operations affecting the œsophagus, or performed through a transthoracia approach require meticulous post-operative care. The replacement of blood lost during the operation must be continued until a satisfactory hæmoglobin level is reached and maintained.

If an œsophageal anastomosis has been used, oral feeding should be withheld for 24–48 hours and then gradually instituted with glucose drinks followed at an early stage with fluid protein, e g skim milk and egg. The intravenous drip must be continued until adequate fluid is taken by mouth.

If a transthoracic approach has been used, the patient may either be placed in an oxygen tent, or given an efficient oxygen inhaler on return from the operating theatre. Excessive bronchial fluid is prone to collect. If this cannot be expelled by encouraging coughing after the administration of small doses of morphia (the foot of the bed may be raised to help), then some other method must be used for aiding in the expulsion of these asphyxiating fluids, such as (1) intravenous injection of nikethamide, (2) by passing a No. 16 French catheter through the nose and then blindly into one or other of the main bronchi, (3) aspiration through a bronchoscope, as described under " Prevention of Chest Complications " (p. 830).

Some bleeding into the pleural cavity is inevitable after operation. If an indwelling pleural catheter has been used, this will be connected, by means of a piece of rubber tubing, with an underwater seal at floor level, and will usually keep the pleural cavity dry If this has not been used, then it will be necessary to perform thoracentesis on alternate days until no more fluid collects, and X-ray shows no evidence of pleural effusion.

Post-operative chemotherapy is essential in these cases if lung and pleural infections are to be prevented

The mortality of gastric resection for carcinoma will vary with the type of case accepted for surgery, and with the extent of the operation. To take great risks is justified in the endeavour to resect the tumour but a high mortality may be experienced. Therefore, no conclusions can be drawn from the mere comparison of mortality rates of different schools or operators.

The mortality figures of all these operations have, however, fallen during the last few years In 1939 the mortality rate for total gastrectomy for carcinoma from all operators was in the neighbourhood of 90 per cent. Ten years later it had dropped to between a half or a third of that figure.

(*See* also operative mortalities given on p. 844.)

Taking all circumstances into consideration and giving every patient the *chance* of relief which the circumstance of the particular case demands, we must continue to aim at a lower mortality and may consider about 10 per cent. in operations for gastric carcinoma as a figure for which we should strive.

BENIGN TUMOURS OF THE STOMACH

Benign tumours of the stomach are being recognized with ever-increasing frequency as a result of the improvement in radiological technique and of the increasing use of gastroscopy.

They may be divided into the epithelial or mucosal and the mesoblastic, usually submucosal, tumours. The former, adenomata and papillomata, may be single or multiple, and there is evidence that they are very prone to undergo malignant degeneration. Removal is indicated if the tumour or tumours become large enough to become pedunculated and cause gastric obstructive symptoms by blocking, or even prolapsing, through the pylorus. Removal is also indicated if they ulcerate or are multiple because of the increased risk of malignant degeneration. Sometimes a malignant tumour is associated with an obviously innocent one.

The mesoblastic tumours may be single or multiple. Small ones may be lipomata, myomata, ectopic pancreas, etc., but while small and if not ulcerated, they need only be subjected to periodic observation The large and ulcerated tumour is usually a leiomyoma, neurilemmoma, or fibromyoma. It is usually single, but may attain very large proportions and is prone to ulcerate, bleed, or cause pyloric obstruction. Some are sarcomatous in nature, and some later undergo malignant degeneration It is usually wiser to resect this form of tumour.

Operative technique.—The abdomen is opened in the usual way and the viscera are explored Small adenomata and papillomata may be well nigh impossible to identify by palpation and may only give the impression of thickened folds. Hence it is well to have their position determined by gastroscopy or X-ray before operation. If they are localized to the antrum a partial gastrectomy will meet the case but if diffusely scattered all over the stomach subtotal gastrectomy, is necessary.

The mesoblastic tumours are more easily felt. If there is any induration of the base of the tumour, or its periphery, a wide resection must be carried out in case the tumour is sarcomatous In the absence of induration or other signs of malignancy a local excision with an ellipse of the gastric wall at the base is usually sufficient if the tumour is attached to the upper stomach. If it lies in the mid stomach a sleeve resection, or if in the lower stomach a partial gastrectomy, is the procedure of choice

DUODENAL ILEUS

Apart from the acute duodenal dilatation sometimes seen in association with acute dilatation of the stomach, a chronic duodenal dilatation is sometimes encountered.* Rarely the distension is enormous. The condition may be associated with epigastric discomfort after meals with belching and vomiting, or there may be a peptic ulcer-like history.

The condition may be an atonic dilatation and extend to the upper jejunum. Sometimes it ceases abruptly at the point where the superior mesenteric artery crosses in front of the third part of the duodenum. It may be mimicked by obstructive lesions, for example, enlarged superior mesenteric glands pressing on the third part of the duodenum, or duodeno-jejunal or pancreatic carcinoma. It must be *differentiated from the dilatation of the proximal half of the duodenum* resulting from the persistence of congenital bands extending from the lateral parietes to the descending part of the duodenum (*see* "Congenital Duodenal Obstruction," p. 791).

In the writer's experience careful examination not infrequently discloses the presence of a small gastric or duodenal ulcer in association with the ileus. Whether this is the cause or a result of the condition is not known.

If the condition appears to be obstructive, ceases abruptly at the point where the superior mesenteric vessels cross in front of the duodenum, and is unassociated with peptic ulcer, duodeno-jejunostomy may give relief In all such cases, however, it is well to institute a course of medical management first. This consists of abdominal exercises to diminish visceroptosis, combined with a diet as for peptic ulceration. If the abdominal wall has been weakened by childbirth or operative scars, a supporting belt may be worn.

Operative technique.—If a peptic ulcer is asociated with the duodenal dilatation, a partial gastrectomy of the Polya type should be performed. The Billroth I operation is obviously unsuitable in the presence of an obstructed duodenum.

In the absence of ulcer, and it being confirmed that the dilatation ends abruptly at the level of the superior mesenteric artery, the third part of the duodenum is exposed by lifting the transverse mesocolon, when it may be seen through the peritoneum running to the root of the mesentery. An opening is made in the mesocolon to the left of the ascending branch of the right colic artery which runs up to anastomose with the middle colic artery Care must be taken to avoid this vessel and the superior mesenteric vessels which lie to the left. The third part of the duodenum is drawn through this peritoneal opening, and a small non-crushing clamp is applied to it in the long axis of the gut. A loop of jejunum of corresponding size and just distal to the flexure is also clamped (Fig 866). An anastomosis is

* D P D Wilkie, *Brit J Surg*, 1921, ix, 204

The diverticulum when isolated may be excised and the resulting opening carefully closed in two layers. It is often recommended and is permissible to invaginate the diverticulum, and carefully repair the muscular defect in the stomach wall. It must be emphasized, however, that this is a dangerous practice in the treatment of a diverticulum adjacent to the cardia, for in such a position the invaginated diverticulum may become congested and act as a ball valve below the œsophageal opening, allowing the entrance of food, fluid and air into the stomach, but preventing its expulsion by eructation. The writer has seen great abdominal distension occur in such a case. In this situation excision of the diverticulum is the treatment of choice.

Duodenal diverticula.—These are recognized in ever increasing numbers with improved radiological techniques. Symptoms sometimes ascribed to them are epigastric fullness after meals, or a duodenal ulcer-like syndrome. It is possible that attacks of obstruction or ulceration may occur in the diverticulum Most commonly the region of the ampulla of Vater is the site of the diverticulum, and it may be hidden in the pancreas or in the retro-peritoneal tissues.

Less commonly the diverticulum may affect the first or the third part of the duodenum where it may be associated with colonic or jejunal diverticulosis.

Operative technique.—Access is by the usual right paramedian, or by a high right transverse incision The latter is valuable if the patient is obese and deep chested. After careful examination of the viscera the hepatic flexure is pulled downwards and to the left, and the outer wall of the duodenum is carefully explored It will usually be necessary to mobilize the duodenum after the method of Kocher (p. 811) The pouch may be found lying flat on the duodenal wall and usually has no muscular coat. When found the base can usually be clamped, or if it has a narrow stalk, ligatured, and closed with fine catgut sutures. An attempt is then made to repair any muscular defect with interrupted sutures of fine catgut on an atraumatic needle, if possible suturing in the transverse axis of the bowel. The proximity of the common bile and pancreatic ducts should be remembered, and the suturing done with great discretion.

If the diverticulum previously demonstrated cannot be found, a small opening may be made in the anterior wall of the duodenum and a finger inserted, when the mouth of the diverticulum may be felt and its relations demonstrated with the finger. If the diverticulum burrows into the pancreas, the duodenum may be separated from the pancreas until the base is reached, the dissection being aided by a finger in the pouch * It is not justifiable to cut widely into the pancreas to deal with a diverticulum, for this may be followed by a pancreatic leak If radiologically certain but difficult to find, or hazardous to remove, an alternative method of treatment is to exclude the duodenum by performing a Polya type of gastrectomy

* N J MacLean, *Surg Gyn & Obst*, 1923 xxxvii, 6

PYLORIC MUSCLE HYPERTROPHY OF ADULTS (MAYLARD)

A condition may affect adults in which pyloric obstruction occurs due to a hypertrophy of the pyloric muscle similar to that seen in childhood.* This is only a rare occurrence, Sir James Walton finding *it seven times in the course of 2,665 gastric operations.*†

Operative technique.—After a general examination, the stomach and duodenum are carefully palpated and inspected for the presence of ulcer. *The hypertrophy is examined*, and an *attempt* made to differentiate it from carcinoma by invaginating a cone of stomach wall into the lumen with a finger to discover if there is an ulcerated edge.

If a chronic ulcer is also present a partial gastrectomy should be performed. In some cases a gastrectomy is performed because the diagnosis is mistakenly believed to be carcinoma.

If pyloric hypertrophy is the sole lesion, and carcinoma can be excluded, a pyloroplasty or gastro-jejunostomy will give good results.

FOREIGN BODIES IN THE STOMACH

The foreign bodies most commonly found in the stomach consist either of single articles swallowed by accident or sometimes multiple bodies swallowed by hysterical people, mental hospital or prison inmates, or by ignorant persons for a wager. In the past the "bezoars" or large aggregations of material, sometimes so massive as to form a cast of the stomach, were more common than nowadays. The material most commonly found in the bezoar was hair—the "hair ball".

When a patient swallows a foreign body he is usually aware of the accident and seeks advice. Smooth objects which have safely negotiated the œsophagus usually pass without incident and even sharper objects such as broken tooth plates, pins, nails, bent wire, may safely pass through the rest of the alimentary tract. Fortunately the majority of such articles are opaque to the X-rays and their position can, therefore, easily be noted. If without symptoms, the patient should be watched, and operation only undertaken if symptoms such as pain or hæmorrhage occur or the object becomes fixed for two to three weeks and is associated with tenderness. If it is decided to operate the patient should be X-rayed just before operation to confirm that the foreign body has not moved onwards, or even been passed. This is essential as bodies which have lain for weeks in the stomach may unexpectedly migrate.

Operative technique.—The stomach should be freely exposed and very carefully examined to locate the foreign body and ascertain if it has perforated the gastric wall. An incision should be made in an

* A. Ernest Maylard, *B M J*, Feb. 20 1904
† J. Walton in "Modern Operative Surgery", 3rd edition

accessible part of the stomach wall after withdrawing the viscus from the abdominal cavity and packing off round it. The gastrotomy opening should be more or less vertical and large enough to enable the foreign body to be withdrawn without damage to the stomach wall. A large incision may be necessary to remove a hair ball intact. The foreign body is removed with forceps and the wall of the stomach closed with two layers of catgut sutures, the first passing through all the layers, and the second only through the seromuscular walls. If the stomach is small or the seat of gastritis a longitudinal incision in its wall had better be closed vertically to increase rather than decrease its lumen, i.e. gastroplasty.

INJURIES OF THE STOMACH

External crushing injuries of the lower thorax or upper abdomen rarely cause gastric damage, though a full stomach may be burst.

Penetrating injuries of the lower chest or upper abdomen may cause perforation of the stomach and this accident may occur during gastroscopy, though it is extremely rare with the flexible instrument. Most commonly the perforation is at the site of a gastric ulcerative lesion, rarely through the intact stomach wall.

Spontaneous rupture of the intact stomach has been reported when large meals have been taken after prolonged starvation. The writer has seen perforation of normal stomach at the edge of a carcinoma as a result of distension of the viscus from a large hæmorrhage.

Clinical picture.—If the stomach is empty at the time of perforation symptoms may be slight at first. If the stomach is full, pain is more severe and rigidity and generalized tenderness develop rapidly. Gastric contents may escape from a penetrating abdominal or thoracic wound. There may be blood in the vomitus.

Treatment.—Operation is indicated once the condition is suspected, though time should be taken to give morphia, set up a blood transfusion and allow the patient to recover from the primary shock.

If there is already a thoracic or abdominal wound this should be enlarged, and exploration undertaken through it, unless it is in an unsuitable position. Otherwise an upper abdominal incision is made. A careful examination of the abdominal viscera is made and blood and gastric contents aspirated from the peritoneal cavity. The stomach is explored on its anterior, and then on its posterior surface after opening the gastro-hepatic or gastro-colic omentum. Any tear is carefully repaired with two layers of sutures. The blood supply of the organ is so free that any bleeding gastric vessel may be ligatured and tears of almost any shape sutured without fear of devitalization. In cases where injury extends from the cardiac region up into the œsophagus an attempt should be made to carry out repair by the abdominal route, though sometimes a *transthoracic transphrenic* approach through the seventh, eighth or ninth intercostal space may be required.

VOLVULUS OF THE STOMACH

Volvulus of the stomach though a very rare condition may occur at any age and is predisposed to by laxity of the gastric ligaments, diaphragmatic hernia, eventration or paralysis of the diaphragm, or by gastric adhesion. The volvulus may be round the long axis of the stomach itself or more commonly round the axis of the gastro-hepatic omentum.

Partial rotation may be symptomless, but rotation of 360 degrees or more may occur. Chronic or recurrent volvulus may cause intermittent attacks of pain and vomiting. Acute volvulus may cause acute gastric obstruction and perhaps vascular occlusion and gangrene, with signs of an acute abdominal emergency.

Treatment.—The acute form is met with and treated as an acute surgical emergency. The volvulus is untwisted, any necrotic part being removed or invaginated. Sleeve resection or Polya gastrectomy may be required.

In chronic forms of volvulus any predisposing lesion should be dealt with, when possible When untwisted, the stomach may be fixed to the liver or parietes in the hope of preventing recurrence. If there is eventration or paralysis of the diaphragm, then the space under the diaphragm must needs be filled by abdominal viscera and in such cases after fixing the stomach the writer recommends that the gastro-colic omentum should be divided to allow the transverse colon to rise and fill the left subphrenic space.

ACUTE PHLEGMONOUS GASTRITIS

This is a rare suppurative form of gastritis. It may arise spontaneously or may be associated with suppurative lesions in other parts of the body, or may arise at the edge of a gastric ulcerative lesion. Submucosal abscesses may develop The acute form arises as an acute emergency with varying degrees of fever, abdominal rigidity and tenderness

Treatment.—The condition is most likely to be met with at laparotomy for a suspected perforated ulcer In the past such methods of treatment as gastric resection or exteriorization, or gastrotomy have been recommended. Nowadays closure of the abdomen followed by chemotherapy with penicillin or other antibiotic is preferable. If an abscess develops it will require drainage.

GASTRIC AND DUODENAL EXTERNAL FISTULA

Such fistulæ may occur as rare complications of abdominal injuries, but are more likely following operations on the stomach or duodenum They may result from perforation of the parietes by a *gastric neoplasm* or perigastric or periduodenal abscess

Treatment.—There is sometimes great fluid loss due to escape of gastric contents and so the first essential is to repair the losses of fluid, salt, sugar and protein by intravenous infusion and feeding with a high protein diet. Severe skin excoriation may occur and is easier to prevent than treat. The skin around the fistula should be painted with a protective paint, e g. industrial barrier cream, aluminium paint or vaseline. At the same time a rubber tube, slightly smaller in diameter than the fistula, should be introduced into the fistula and connected with a low pressure *continuous suction apparatus. Some*times such patients can be nursed in the prone position on a Stryker frame or special mattress in such a way that the discharge from the fistula will drop directly out on to an underlying receptacle.

A dressing of gauze soaked in peptone or white of egg solution is sometimes used to inactivate the digestive enzymes.

Sometimes a catheter, e.g. Ryle's, can be passed through the nose or the fistula to enter the duodenum beyond the fistula. If so nutriments and any collected digestive juices may be introduced into the duodenum by this route.

The mouth must be kept moist and clean, though fluid intake by mouth should not be excessive. Solid foods may be taken by mouth and may be partly absorbed.

By suitably reducing the size of the catheter in the fistula, the latter usually heals spontaneously.

If the fistula is slow in healing, particularly if gastric, surgery will be indicated If the fistula is of malignant origin surgery will always be required. In non-malignant cases this may take the form of closure of the fistulous opening in the stomach. In the case of gastric carcinoma or ulcer, gastrectomy may be required. It should be emphasized that one should not be in too much of a hurry to operate on a duodenal fistula, for the duodenal tissues are inflamed, friable and difficult to isolate. If there is an obstructive or ulcerative duodenal lesion, gastrectomy or gastro-enterostomy and gastric transection to exclude the fistula may be required If the fistula follows a Polya partial gastrectomy then it may be necessary to explore the gastro-jejunal anastomosis to exclude or correct any obstruction of the afferent jejunal loop

CHAPTER XVI

OPERATIONS ON THE LIVER AND ITS EXCRETORY APPARATUS

By G. GREY TURNER

Surgical anatomy of the liver. Mobility.—This organ is normally possessed of considerable mobility. It descends in the erect posture and recedes under the dome of the diaphragm when the recumbent position is assumed, and it moves laterally with the body. When the abdomen is opened for surgical purposes this mobility allows the organ to be displaced inwards and forwards, and to be so rotated on its horizontal axis that its under-surface can be made to look almost anteriorly. In this way the hilum (the portal or transverse fissure) and the deeper ducts are made accessible. This normal mobility varies and is often interfered with by adhesions, or by other pathological conditions which shorten the ligaments or make them rigid.

Position.—The position of the liver varies in different types of individual. In tall spare subjects with narrow chests the organ is commonly high up under the dome of the diaphragm and is then difficult of access. In the broad-chested the costal margin is splayed out, the arch of the diaphragm flatter, and the liver correspondingly more easily exposed. These natural variations must be borne in mind when the gall-bladder is visualized by cholecystography, for its position varies with that of the liver.

Consistence.—The organ is normally plastic, and this quality is of importance surgically, because by gentle but firm, slow pressure a good hold may be taken without doing harm. The plasticity is largely due to the amount of blood which the liver contains. For the same reason the organ is friable, its integrity largely depending upon its tough, strong capsule

Blood-vessels.—For the most part the blood is contained in the hepatic veins. These are simply spaces lined by endothelium; they are without valves, and are not collapsible. The amount of blood they contain is large, but it is under very low pressure. The branches of the hepatic artery are comparatively few; they run with the portal vein, and are the only vessels in the liver which spout when cut. They are for the most part terminal vessels and their ligation is followed by infarction.

Relation of the pleura to the liver.—The pleural recess descends to within an inch of the costal margin, and, whatever the position of the lung, this recess never varies, so that to reach the dome of the liver from the thoracic parietes the two layers of the pleura must always be traversed. It must be realized that the dome of the liver and the summit of the diaphragm are surrounded by the base of the lung and by the pleural sac. These points are illustrated in Fig. 368.

*Morison's pouch** or the hepatic pouch, is that part of the peritoneal cavity which lies just below the right lobe of the liver. It is bounded inferiorly by the ascending layer of the transverse mesocolon and the hepatic flexure; internally by the peritoneum covering the spine, the free edge of the gastro-hepatic omentum and the foramen of Winslow between the two. The fluid from a leaking gall-bladder or common duct is apt to collect in this area.† (Fig. 367.)

Anomalies.—Variations of surgical importance are exceedingly uncommon. A tongue-shaped process springing from the lower border of the right lobe is occasionally present. Sometimes it is so large as to form a separate mass, then known as Riedel's lobe. It may have a broad connection with the liver, or may be attached by a narrow thin pedicle. This lobe may hide the gall-bladder, or the latter may be attached to it.

Surgical anatomy of the gall bladder and biliary ducts.—The fundus of the gall-bladder usually lies behind the tip of the ninth costal cartilage. The latter may be very difficult to identify in the obese, and in such subjects a very useful surface-marking is the point where a line drawn from the left anterior superior iliac spine through the umbilicus reaches the right costal margin (John Clay). When pathologically distended the neck of the gall-bladder becomes very prominent

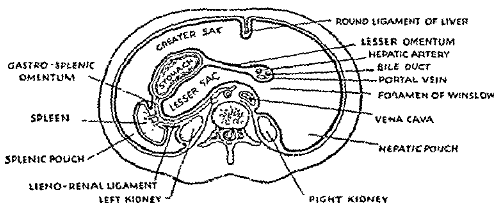


Fig 367. – Transverse section of the peritoneal cavity at the level of the foramen of Winslow.

at its lower border, and is known as the infundibulum, or Hartmann's pouch. This part of the gall-bladder is most important, for it lies over the cystic duct, which it may obscure, and it is this part of the viscus which most readily becomes adherent to the duodenum. The ducts are seldom found as they appear in the majority of anatomical diagrams, in which they are shown dissected from the surrounding tissues and straightened out; similarly, the measurements usually given refer to the ducts when thus dealt with The supraduodenal portion of the common duct is usually covered by the duodenum, and is frequently completely hidden by adhesions between the infundibulum

* Rutherford Morison, 1853–1939, of Newcastle-upon-Tyne
† B.M.J., 1894, ii, 968

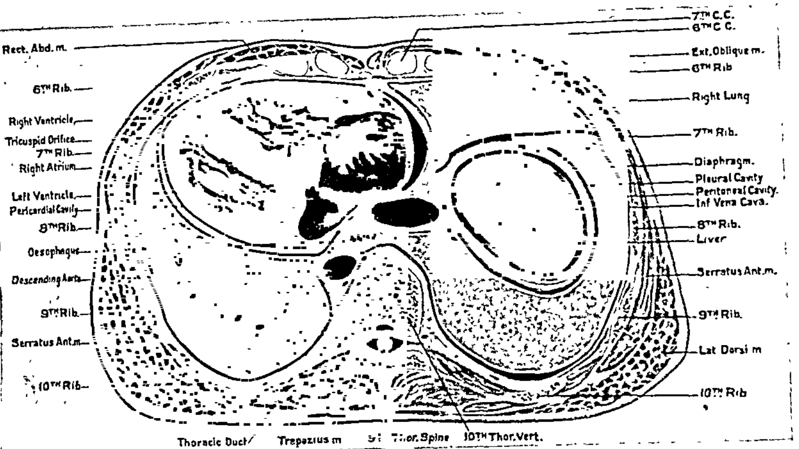


Fig. 368.—Transverse section at level of tenth thoracic vertebra, showing dome of liver completely surrounded by peritoneum, diaphragm, lung and pleural cavity.

(Reproduced by permission from "An Atlas illustrating the Topographical Anatomy of the Neck, Thorax, Abdomen and Pelvis," by *Johnston Symington*.)

of the gall-bladder and the bowel, forming the cholecysto-duodeno-colic ligament. It can, however, always be easily exposed by separating pathological adhesions and by gently drawing the duodenum downwards by gauze stripping. When not distorted by contained calculi

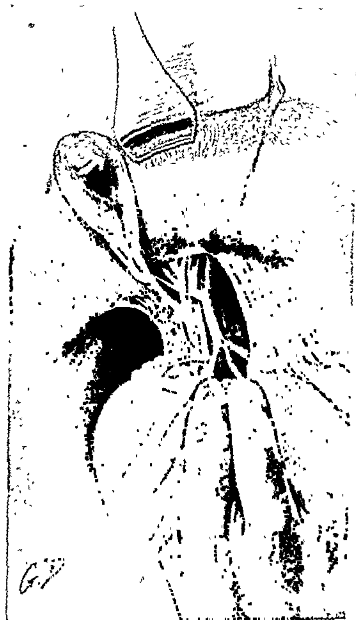


Fig. 369.—Anatomy of th[illegible], their relations to blood-vessels, and exposure of the common duct obtained by traction on the duodenum

the lower end of the common duct tapers rapidly towards its narrowest part. Attention must be drawn to the frequency with which small vessels, both arteries and veins, cross the common duct either to reach the head of the pancreas or the cystic duct and gall-bladder. (Fig. 369.)

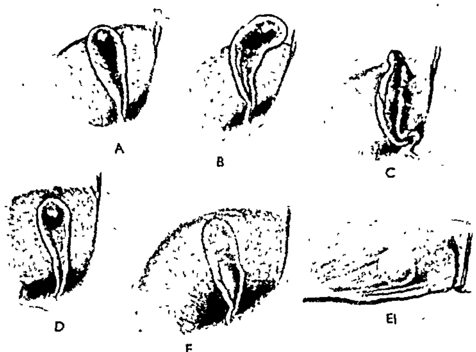


Fig. 370.—Usual types of gall-bladder.

A. As most commonly found. *B*. Pendulous. *C*. With a mesentery. *D*. Hidden *E*. Buried *E1*. Upper surface of type *E*.

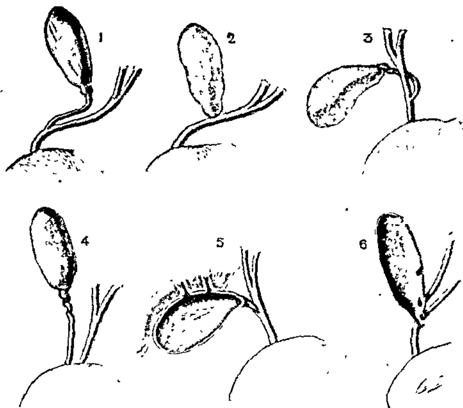


Fig. 371.—Some anomalies of bile-ducts.

1 Long cystic duct running parallel to common duct before uniting. 2 Very short cy[illegible] 3 [illegible] arrangement of cystic duct. 4 Cystic duct opening independently into duodenum 5 [illegible] ducts opening directly into gall-bladder 6. Hepatic ducts opening directly into gall-[illegible] common duct originating from latter.

Anomalies.—The gall-bladder is nearly always in its normal situation, but it frequently presents the minor alterations shown in Fig. 370 Very rarely it may be entirely absent, or may be situated on the under surface of the left lobe, or may be in its normal situation but entirely embedded in the liver substance, or it may be either double or divided by a septum into two parts The ducts present many variations (Fig. 371), the most important being (1) a long cystic duct running parallel with the common duct for a considerable distance; (2) a very short cystic duct; (3) various spiral arrangements in which the cystic duct winds round the hepatic ducts before uniting with them; (4) variations in union of the hepatic ducts, the latter either uniting much lower than normal, or opening separately into the duodenum; (5) accessory hepatic ducts; (6) hepatic ducts opening directly into the gall-bladder and the common duct originating from the latter. There are also many alterations in the ducts which are pathological but which may be mistaken for anatomical variations. The relations of the hepatic artery and its cystic branch are very variable. Of 100 subjects examined by E. R. Flint of Leeds, in only 34 was the arrangement of the ducts and vessels that usually described as normal. In about 30 per cent. of subjects the right hepatic artery or the cystic artery was found crossing in front of the common duct or the common hepatic duct, and in 16 per cent. an accessory cystic artery was found passing in front of the ducts to the gall-bladder. For these reasons the surgeon, when operating on the neck of the gall-bladder, or the common duct, must always satisfy himself of the exact relationships by actual visual observation.

OPERATIONS ON THE LIVER

Suture of the liver.—This may be necessary in many circumstances quite apart from deliberate resection, as for instance when the liver is accidentally torn during cholecystectomy. The suture material ought to be catgut—for big tears No. 1, for smaller tears No 0. It must be passed with a round needle of sufficient size of eye to allow the catgut to follow without tearing too big a hole, or better still of the eyeless pattern. Special blunt flexible needles are sometimes recommended (Konsnetzoff) but, though certainly convenient, they are not really necessary, and as they are not often required they are usually missing when wanted. Most of the hæmorrhage is from branches of the hepatic veins, and readily ceases when the liver surfaces are brought together Spouting vessels will be branches of the hepatic artery, and should be caught and tied with catgut like any other vessel, but bleeding from big veins may have to be controlled by passing a purse-string suture round the opening, as shown in Fig 378, the flow being temporarily controlled by putting the finger-tip on the orifice of the vein. The edges of the wound may be drawn together with as many stitches as are necessary to secure rough apposition, about one to the inch being required for this purpose The needle is inserted ½ in. from the edge of

the tear, should reach nearly to the bottom of the wound to be closed, and should usually be brought out in the middle of the tear and re-inserted, so as to appear at a corresponding point on the opposite side of the wound. These sutures are gently drawn together, the knot of the stitch being kept at the side rather than over the centre. This suture will bring the depths of the wound together and will stop most of the bleeding. Exact apposition is then secured by stitches of finer catgut passed close to the edge, at intervals of about ¼ in. These sutures should be interrupted, because it is important to avoid the development of a hæmatoma in the liver wound, and it is much better that any oozing should find its way to the surface between interrupted stitches. When the capsule is deficient, or unusually friable, the sutures may not hold, and it may then be necessary to use some structure to support the stitch, after the plan of the old-fashioned " button suture". For this purpose magnesium plates have been recommended, but they may not be at hand when required, and it is better to rely on some structure which is always available. If the tear is on the upper surface of the liver it may be possible to pass the sutures through the triangular ligament; or the latter may be detached and laid over the proposed line of suture, so that the stitch is passed through it on both sides. Or a strip of the ligament may be cut away and used for this purpose in any situation, or a piece of parietal peritoneum or rectus sheath, or a portion of omentum, may be utilized. (Fig. 372.) (*See also* pp. 898–901.)

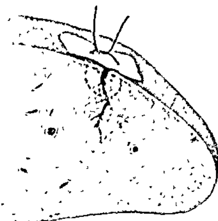


Fig. 372.—Suture passed through piece of triangular ligament that has been completely detached for the purpose.

Operations for Fixation of the Liver

Indications.—True hepatoptosis is very rare, and mild degrees of prolapse of the liver are only part of a general visceroptosis and can rarely justify surgical intervention. Intervention is very rarely indicated, but the possible methods illustrate the principles of the technique of fixation of any abdominal viscus, and may therefore be included here.

Choice of operation.—The methods available are:

(1) Direct suture to the parietes. (2) Shortening of the ligaments.
(3) Formation of adhesions between the liver and the parietes.
(4) Gauze packing.

The technique is described in the earlier editions of this work.

Operations for Injury

Injuries to the liver may be associated with a parietal wound, or may be entirely closed. The former type is often the result of gunshot

Anomalies.—The gall-bladder is nearly always in its normal situation, but it frequently presents the minor alterations shown in Fig. 870 Very rarely it may be entirely absent, or may be situated on the under surface of the left lobe, or may be in its normal situation but entirely embedded in the liver substance, or it may be either double or divided by a septum into two parts. The ducts present many variations (Fig. 871), the most important being (1) a long cystic duct running parallel with the common duct for a considerable distance; (2) a very short cystic duct; (3) various spiral arrangements in which the cystic duct winds round the hepatic ducts before uniting with them; (4) variations in union of the hepatic ducts, the latter either uniting much lower than normal, or opening separately into the duodenum; (5) accessory hepatic ducts; (6) hepatic ducts opening directly into the gall-bladder and the common duct originating from the latter. There are also many alterations in the ducts which are pathological but which may be mistaken for anatomical variations. The relations of the hepatic artery and its cystic branch are very variable. Of 100 subjects examined by E. R. Flint of Leeds, in only 34 was the arrangement of the ducts and vessels that usually described as normal. In about 30 per cent. of subjects the right hepatic artery or the cystic artery was found crossing in front of the common duct or the common hepatic duct, and in 16 per cent. an accessory cystic artery was found passing in front of the ducts to the gall-bladder. For these reasons the surgeon, when operating on the neck of the gall-bladder, or the common duct, must always satisfy himself of the exact relationships by actual visual observation.

OPERATIONS ON THE LIVER

Suture of the liver.—This may be necessary in many circumstances quite apart from deliberate resection, as for instance when the liver is accidentally torn during cholecystectomy. The suture material ought to be catgut—for big tears No. 1, for smaller tears No. 0. It must be passed with a round needle of sufficient size of eye to allow the catgut to follow without tearing too big a hole, or better still of the eyeless pattern Special blunt flexible needles are sometimes recommended (Konsnetzoff) but, though certainly convenient, they are not really necessary, and as they are not often required they are usually missing when wanted Most of the hæmorrhage is from branches of the hepatic veins, and readily ceases when the liver surfaces are brought together. Spouting vessels will be branches of the hepatic artery, and should be caught and tied with catgut like any other vessel, but bleeding from big veins may have to be controlled by passing a purse-string suture round the opening, as shown in Fig. 878, the flow being temporarily controlled by putting the finger-tip on the orifice of the vein. The edges of the wound may be drawn together with as many stitches as are necessary to secure rough apposition, about one to the inch being required for this purpose. The needle is inserted ½ in. from the edge of

the tear, should reach nearly to the bottom of the wound to be closed, and should usually be brought out in the middle of the tear and re-inserted, so as to appear at a corresponding point on the opposite side of the wound. These sutures are gently drawn together, the knot of the stitch being kept at the side rather than over the centre. This suture will bring the depths of the wound together and will stop most of the bleeding. Exact apposition is then secured by stitches of finer catgut passed close to the edge, at intervals of about ¼ in. These sutures should be interrupted, because it is important to avoid the development of a hæmatoma in the liver wound, and it is much better that any oozing should find its way to the surface between interrupted stitches. When the capsule is deficient, or unusually friable, the sutures may not hold, and it may then be necessary to use some structure to support the stitch, after the plan of the old-fashioned "button suture". For this purpose magnesium plates have been recommended, but they may not be at hand when required, and it is better to rely on some structure which is always available. If the tear is on the upper surface of the liver it may be possible to pass the sutures through the triangular ligament; or the latter may be detached and laid over the proposed line of suture, so that the stitch is passed through it on both sides. Or a strip of the ligament may be cut away and used for this purpose in any situation, or a piece of parietal peritoneum or rectus sheath, or a portion of omentum, may be utilized. (Fig. 872.) (*See also* pp. 898-901.)

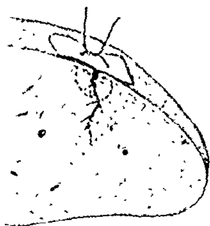


Fig. 372.—Suture passed through piece of triangular ligament that has been completely detached for the purpose.

Operations for Fixation of the Liver

Indications.—True hepatoptosis is very rare, and mild degrees of prolapse of the liver are only part of a general visceroptosis and can rarely justify surgical intervention. Intervention is very rarely indicated, but the possible methods illustrate the principles of the technique of fixation of any abdominal viscus, and may therefore be included here.

Choice of operation.—The methods available are:

(1) Direct suture to the parietes. (2) Shortening of the ligaments.
(3) Formation of adhesions between the liver and the parietes.
(4) Gauze packing.

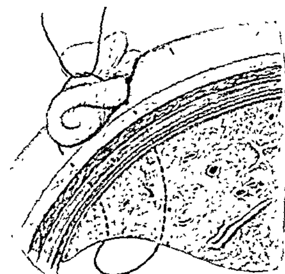
The technique is described in the earlier editions of this work.

Operations for Injury

Injuries to the liver may be associated with a parietal wound, or may be entirely closed. The former type is often the result of gunshot

wounds or stabs In civilized countries the closed injuries, due to crushes or motor-car accidents are the commonest. It is important to remember that pathological conditions, such as fatty *degeneration and venous congestion*, predispose to rupture. These injuries are often associated with damage to other parts, especially the lower ribs, the diaphragm, the lung and pleura, or the right kidney, or more rarely one of the hollow viscera. Sometimes the injury is entirely beneath the capsule. The right lobe is involved five times more frequently than the left and the convexity twice as often as the under surface.

Indications.—In compound injuries, including the gunshot wounds and stabs met with in civil life, the surgeon must always operate. In closed injuries the indications for interference are the severity and duration of the shock, evidences of increasing hæmorrhage, and persistent rigidity. The surgeon must not be misled by a slow pulse, which is sometimes present even with severe lacerations. It is better to operate early than to leave the case in doubt, because in these injuries a low-grade infection is apt to occur, and the records show that the earlier the operation the better the results. In subcapsular injuries the shock and signs of hæmorrhage may not be extreme, but secondary *rupture into the peritoneum* or bile-ducts, or infection, are apt to supervene, and it is in these cases that liver embolism especially occurs. The rule must therefore be to operate when in doubt.



[illegible] ugh liver [illegible] uze. In [illegible] tight.

Preparatory treatment.—It is a mistake to hurry patients suffering from abdominal injuries straight to the operating-theatre. Time should be allowed for them to get over the primary shock In this condition the bleeding is often partially controlled by the abdominal rigidity, and may become furious as soon as the abdomen is opened. It is therefore very important that everything should be in readiness before the operation is begun. This is one of the conditions in which blood-transfusion is almost certain to be required, and the surgeon should be prepared to have it carried out in the course of the operation. (*See* p 595.) The preliminary use of morphia is valuable, but it must not be given sooner than half an hour before operation lest it tend to increase hæmorrhage by decreasing the guarding rigidity If there is much distension, a stomach-tube may be passed, for distension is a

great handicap in operating on the upper abdomen, and it is particularly apt to be found in the unprepared patient. For the same reason a rectal tube may be useful.

Technique.—General anæsthesia is best and complete relaxation essential. The steps of the operation are:—

1. Rapidly determine the site of the injury.
2. Temporarily arrest hæmorrhage.
3. Expose the tear.
4. Deal with the tear by suture or gauze packing, or both
5. Deal with associated injuries.
6. Attend to the peritoneal toilet.
7. Close the abdominal incision.

The abdomen should be opened in the middle line by an incision which extends from the highest point of the costal angle to the umbilicus. On first opening the belly there will probably be a gush of blood, but this is only what has collected in the peritoneal cavity and is to be disregarded, and the surgeon must rapidly discover by palpation the source of the hæmorrhage. Having determined that the liver is the organ injured, he must take steps for the temporary arrest of the hæmorrhage. The method of Hogarth Pringle* may be tried. This consists of manual compression of the structures in the edge of the gastro-hepatic omentum. If this plan does not succeed, gauze must be thrust into the tear or about it, while clots in the neighbourhood are rapidly cleared away so that the exact extent of the injury can be determined. For removing clots the culled hand used as a ladle is quicker and safer than the sucker. At this stage the reverse Trendelenburg position and elevation of the loin may be of great assistance.

The next step is to deal with the tear, and the method to be employed depends largely on its accessibility, for sometimes it can be felt but cannot be readily exposed Large, nearly separated fragments of liver tissue (it may be a considerable part of a lobe) are best completely removed, as otherwise necrosis and sepsis are likely to follow. If the gall-bladder is torn from its attachments, it should be similarly dealt with Any tear which can be exposed sufficiently for the purpose should be sutured, the most inaccessible part, usually posterior, being dealt with first. The sutures should be of No. 1 catgut and interrupted. A large round-bodied needle is used, and ample bites must be taken, as there is a great tendency for the sutures to cut out. The ends of the first stitch are left long and held, to effect traction until the next stitch has been tied, after which they can be cut short In this way hæmorrhage is diminished. A very ragged tear, especially if there is any question of conveyed infection, as in gunshot wounds, can sometimes be cleanly excised and the edges brought into good position. If the wound cannot be completely sutured, as much as possible should be dealt with in this way and the remainder treated by packing. The

* "Notes on the Arrest of Hepatic Hæmorrhage due to Trauma," *Ann Surg*, Oct., 1908, xlviii, 541.

gauze employed should be dry and dusted with one of the antiseptic powders (sulpha group and penicillin) or sterilized boracic acid powder. It is not wise to rely on a merely aseptic pack. The gauze may have to be held in position by one or more catgut stitches tied over it, or by another pack pressing the gauze-filled tear up against the diaphragm or parietes. The neighbouring viscera should be protected from the gauze by strands of rubber tissue. Another plan is to pack the omentum into the wound in the liver or to stitch that structure over a large superficial laceration or to pack it with one of the absorbable hæmostatic gauzes. When the tear has been dealt with, associated injuries must receive attention, special care being taken not to miss a laceration of any of the hollow viscera.

The final stage in the operation is the toilet of the peritoneum. Large clots in the vicinity and any fragments of liver should be removed. Loose fragments may be a source of infection or keep open a sinus until removed as "liver sequestra" (Ruscoe Clarke*). It is not necessary to attempt to clear all the blood out of the peritoneal cavity, and irrigation is better avoided: A track to the surface must always be provided by a rubber tissue drain or a soft split tube, as there may be leakage of bile. If the patient is very ill too much time should not be spent on the closure of the parietal wound but three or four strong through-and-through sutures must always be inserted.

Lacerations which involve the hilum are particularly serious, as the larger vessels or bile-ducts are apt to be torn across. If, as often happens, *the patient is in extremis, the most the surgeon can do is* rapidly to clear away clots and apply large clamps to the bleeding vessels, the handles of the clamps being brought out of the wound. If the condition permits, the parts may be exposed and examined after the vessels have been temporarily clamped. The clamp being used as a tractor, the parts in its grasp are gently drawn towards the surface for examination. In this way a tear in the portal vein may be exposed and sutured, or perhaps an injured bile-duct repaired. In any event, it can at least be arranged that only so much of the vessel is clamped as is necessary to stop hæmorrhage.

Gunshot wounds and stabs in civil life should always be explored, because of the likelihood of associated injuries and because exploration gives an opportunity of removing foreign bodies like wads or portions of clothing and otherwise anticipating sepsis. The entrance wound must be excised, but it will generally be necessary to open the peritoneal cavity by a more conveniently placed incision

Subcapsular injuries.—If this type is found, the capsule over it should be divided, liver débris and clots removed, and the rent dealt with by suture, or as already described.

Late interference in liver wounds.—Operative interference may be considered necessary after a delay of some days. In these circumstances, if there is no active hæmorrhage, it is wisest to be content to

* *Brit. Journ. Surg.*, 1941, cxii, 344

remove débris and clots and to provide drainage. Unless for some special reason, secondary suture should not be attempted.

INJURIES TO THE GALL-BLADDER AND BILE DUCTS

These are usually associated with injuries of the liver, but may occur independently. The usual sites are shown in Fig. 374. If free bile is found on exploration of the peritoneal cavity, the gall-bladder and ducts must be carefully inspected, and the complete extent of the damage determined before the obvious injury is repaired. When the gall-bladder is injured the tear can be sewn up, or used for drainage, or the viscus removed. Complete severance of the cystic duct is best dealt with by cholecystectomy. An attempt must always be made to repair the deeper ducts. The ends are apt to retract and be difficult to find. The aim should be end-to-end apposition, after freshening the torn margins. External drainage must be provided in every case, and is all that can be done if the torn duct cannot be located. Subsequent management is dealt with on p. 960.

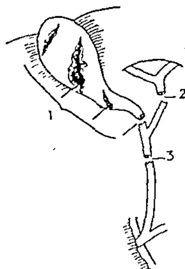


Fig. 374.—Injuries to the gall-bladder and ducts.

In 1 cholecystectomy is indicated; in 2 and 3 the duct ought to be repaired.

After-treatment.—Shock and the effects of hæmorrhage must be dealt with, and these may require the transfusion of blood or glucose saline.

When to remove the gauze.—Liver tissue does not repair rapidly and therefore no attempt should be made to remove gauze packed into a rent for the purpose of arresting hæmorrhage sooner than the eighth day. As long as fourteen days may elapse before it can be removed without running the risk of restarting bleeding. The gauze should first be loosened gently by pulling on the edges, and at the least sign of hæmorrhage the process must be stopped and forty-eight hours allowed to elapse before a further attempt is made.

Complications.—A mild but insidious form of *sepsis* frequently occurs It may clear up in a week or so, or be associated with a fatty change in the liver which often goes on to a fatal termination as one of the forms of "Liver Death." Quite apart from infection a toxic state may develop affecting the kidneys, which may end fatally. *Secondary hæmorrhage* is not uncommon from the seventh to the twenty-first days. If at all serious, no time should be lost in exploring the wound under anæsthesia. It is to be treated by clearing out all clots and débris from the gauze tract with a sharp spoon, used gently. The area should then be packed with strands of dry gauze dusted with

one of the antiseptic powders. If the hæmorrhage is very persistent or recurrent the gauze may be soaked in turpentine, all excess being first squeezed out and care being taken to protect the surrounding skin from the irritation of the chemical. Horse-serum may be used in the same way; blood transfusion will be helpful. *Biliary fistula*, if from the liver substance, will heal spontaneously, though it may take a long time; if the larger ducts have been injured, secondary operative interference may be required. If bile is passing with the fæces, there is a fair probability of spontaneous healing, even after many months

Results.—Statistics on the results of operation for injuries of the liver are very difficult to compile because of the frequent association of other injuries, and because, as a rule, fatal cases are not reported. These accidents are extremely dangerous, and when they are severe enough to demand operation the mortality is probably about 50 per cent. Some of the conditions met with are so serious that they are of necessity fatal, and no operative interference, however prompt, can save life. Death usually occurs early, as the result of hæmorrhage or shock; later, it is frequently due to sepsis and its consequences. In civil life closed ruptures have proved more serious than gunshot wounds and stabs.

LIVER ABSCESS

There are two principal varieties of liver abscess: (1) as a complication of amœbic dysentery, usually called "Tropical Abscess", (2) following some other intra-abdominal infection such as appendicitis.

Tropical abscess, due to the *Entamœba histolytica*, has rapidly diminished since the almost routine use of emetine in suspected cases. However, abscesses due to this cause are still occasionally met with and sometimes in patients who have long left the tropics or who have never been abroad. It is in such circumstances that the condition is often for long unsuspected and may be overlooked. In the second group, liver abscess following appendicitis may be a sequel to those rare cases of pylephlebitis which recover. Among other causes are typhoid infections and cholangitis Suppuration in a hydatid cyst may be indistinguishable from solitary abscess with some other ætiology.

Tropical Hepatitis and Abscess

Preliminary treatment and aspiration.—The whole treatment of tropical abscess of the liver has been placed on a new footing since the value of emetine has become appreciated in the treatment of amœbiasis Previous knowledge was largely derived from cases much further advanced than are likely to be met with to-day, and the treatment was based on the assumption that the pus of such abscesses was pyogenetic, whereas in the large majority of cases it is sterile. These abscesses are commonest in the right lobe, but in about 40 per cent. of cases they are multiple. There is abundant evidence to show that they can recover spontaneously, and the aim of treatment

at the present time is to imitate the processes by which nature brings this about.

One essential is to saturate the circulating lymph with emetine which is inimical to the amœba. In some cases this is all that is required, the pus becomes innocuous and either disappears or becomes inspissated. When further aid is necessary, the tension in the abscess must be relieved so as to encourage an outpouring of emetine-saturated lymph from its walls and to allow of their collapse or contraction. This is done by the withdrawal of pus This can be carried out more conveniently and safely by a syringe than by an aspirator. A large 20 c.c. Record with a long needle of wide bore answers very well. Several syringefuls may be removed, but only as much as flows easily should be withdrawn at one time. The process may have to be repeated, but it is not essential that all the pus should be removed. The routine treatment ought therefore to consist of (*a*) intramuscular injection of emetine hydrochloride, 1 gr. daily for ten days; (*b*) removal of pus either with a large exploring syringe or an aspirator. The evacuation of pus may be carried out when the case is first seen, if there are urgent symptoms due to the size or situation of the abscess, but it is better deferred until a course of emetine has been administered. If there is evidence of secondary infection, or the case is not doing well, open incision may be subsequently required. The preliminary or simultaneous treatment by emetine is necessary in all cases, and aspiration may further help to render subsequent open operation more successful.

Aspiration with siphon drainage has been warmly advocated by Sir Leonard Rogers, and it may be an advantage where adequate care in subsequent dressing cannot be secured. A special trocar with a flexible sheath is used and is left in the abscess cavity, the tube being allowed to lie in a bottle or basin of antiseptic fluid. The instrument is introduced after the situation of the pus has been determined. Only local anæsthesia is necessary, and the trocar can be removed in a few days, the wound healing rapidly.

Further indications for treatment.—What follows applies to the treatment of (1) amœbic liver abscess which has not responded to treatment already outlined, and (2) intrahepatic abscesses from other causes.

Open incision.—In the localization of the abscess, X-ray examination under the fluorescent screen has proved invaluable, and should always be employed to supplement the ordinary clinical signs Before actually operating, the surgeon must demonstrate the presence of pus by means of the exploring syringe. The needle should be of the size and length used for spinal anæsthesia. When there are good grounds for suspecting an abscess, one puncture should be made at the spot at which all the indications point to pus. If pus is found, it is better to be prepared to proceed with the operation, either at once or on the next day, further delay being inadvisable. If an abscess which has

one of the antiseptic powders. If the hæmorrhage is very persistent or recurrent the gauze may be soaked in turpentine, all excess being first squeezed out and care being taken to protect the surrounding skin from the irritation of the chemical. Horse-serum may be used in the same way; blood transfusion will be helpful. *Biliary fistula*, if from the liver substance, will heal spontaneously, though it may take a long time; if the larger ducts have been injured, secondary operative interference may be required. If bile is passing with the fæces, there is a fair probability of spontaneous healing, even after many months.

Results.—Statistics on the results of operation for injuries of the liver are very difficult to compile because of the frequent association of other injuries, and because, as a rule, fatal cases are not reported. These accidents are extremely dangerous, and when they are severe enough to demand operation the mortality is probably about 50 per cent. Some of the conditions met with are so serious that they are of necessity fatal, and no operative interference, however prompt, can save life. Death usually occurs early, as the result of hæmorrhage or shock; later, it is frequently due to sepsis and its consequences. In civil life closed ruptures have proved more serious than gunshot wounds and stabs.

LIVER ABSCESS

There are two principal varieties of liver abscess: (1) as a complication of amœbic dysentery, usually called "Tropical Abscess", (2) following some other intra-abdominal infection such as appendicitis.

Tropical abscess, due to the *Entamœba histolytica*, has rapidly diminished since the almost routine use of emetine in suspected cases. However, abscesses due to this cause are still occasionally met with and sometimes in patients who have long left the tropics or who have never been abroad. It is in such circumstances that the condition is often for long unsuspected and may be overlooked. In the second group, liver abscess following appendicitis may be a sequel to those rare cases of pylephlebitis which recover. Among other causes are typhoid infections and cholangitis. Suppuration in a hydatid cyst may be indistinguishable from solitary abscess with some other ætiology.

Tropical Hepatitis and Abscess

Preliminary treatment and aspiration.—The whole treatment of tropical abscess of the liver has been placed on a new footing since the value of emetine has become appreciated in the treatment of amœbiasis. Previous knowledge was largely derived from cases much further advanced than are likely to be met with to-day, and the treatment was based on the assumption that the pus of such abscesses was pyogenetic, whereas in the large majority of cases it is sterile. These abscesses are commonest in the right lobe, but in about 40 per cent. of cases they are multiple. There is abundant evidence to show that they can recover spontaneously, and the aim of treatment

at the present time is to imitate the processes by which nature brings this about.

One essential is to saturate the circulating lymph with emetine which is inimical to the amœba. In some cases this is all that is required, the pus becomes innocuous and either disappears or becomes inspissated. When further aid is necessary, the tension in the abscess must be relieved so as to encourage an outpouring of emetine-saturated lymph from its walls and to allow of their collapse or contraction. This is done by the withdrawal of pus. This can be carried out more conveniently and safely by a syringe than by an aspirator. A large 20 c.c. Record with a long needle of wide bore answers very well. Several syringefuls may be removed, but only as much as flows easily should be withdrawn at one time. The process may have to be repeated, but it is not essential that all the pus should be removed. The routine treatment ought therefore to consist of (*a*) intramuscular injection of emetine hydrochloride, 1 gr. daily for ten days; (*b*) removal of pus either with a large exploring syringe or an aspirator. The evacuation of pus may be carried out when the case is first seen, if there are urgent symptoms due to the size or situation of the abscess, but it is better deferred until a course of emetine has been administered. If there is evidence of secondary infection, or the case is not doing well, open incision may be subsequently required. The preliminary or simultaneous treatment by emetine is necessary in all cases, and aspiration may further help to render subsequent open operation more successful.

Aspiration with siphon drainage has been warmly advocated by Sir Leonard Rogers, and it may be an advantage where adequate care in subsequent dressing cannot be secured. A special trocar with a flexible sheath is used and is left in the abscess cavity, the tube being allowed to lie in a bottle or basin of antiseptic fluid. The instrument is introduced after the situation of the pus has been determined. Only local anæsthesia is necessary, and the trocar can be removed in a few days, the wound healing rapidly.

Further indications for treatment.—What follows applies to the treatment of (1) amœbic liver abscess which has not responded to treatment already outlined, and (2) intrahepatic abscesses from other causes.

Open incision.—In the localization of the abscess, X-ray examination under the fluorescent screen has proved invaluable, and should always be employed to supplement the ordinary clinical signs. Before actually operating, the surgeon must demonstrate the presence of pus by means of the exploring syringe. The needle should be of the size and length used for spinal anæsthesia. When there are good grounds for suspecting an abscess, one puncture should be made at the spot at which all the indications point to pus. If pus is found, it is better to be prepared to proceed with the operation, either at once or on the next day, further delay being inadvisable. If an abscess which has

been confidently diagnosed is not found by single puncture, the patient should be put under anæsthesia, so that as many punctures as are necessary can be made, but no puncture should be made without careful consideration of the direction and the depth to which the needle is introduced. When the abscess is located, the surgeon can proceed at once with its evacuation. Abscesses on the summit of the right lobe of the liver, and especially chronic ones, may evade discovery by the needle in a remarkable way. If there is sound evidence for believing that such an abscess is present, and it cannot be found by the needle, the abdomen should be opened, and, if the diagnosis be then confirmed, the necessary operation should be performed for the evacuation of the pus either through the same incision or by some other approach.

The route to be employed for the treatment of abscess depends on its situation. In those rare cases in which the abscess points externally, it should be opened in that situation, and it will then simply be a question of making an incision for the evacuation of pus and the introduction of a tube.

Abdominal route.—If the abscess presents downwards, it must be opened by an abdominal incision over the site of the swelling. This may be vertical, either in the middle line or through the rectus muscle If the abscess is on the under surface of the right lobe, a transverse incision just below the costal margin is very convenient. Should the abscess be found adherent to the parietes, the adhesions should not be disturbed, and direct opening should be made into the cavity through the adherent areas. If, on the other hand, the abscess is not adherent, the incision must be so enlarged that an opening can be made directly into its cavity without obliquity. The area must then be packed off with gauze and the abscess incised, the surgeon taking great care, if it is near the border of the liver, that he does not thrust any instrument right through that organ to its under-surface. When the abscess is emptied it may be possible to place one or two catgut sutures between the liver, near the margin of the opening, and the parietes. In any case, the tube should be wrapped round with gauze and, as far as possible, made quite tight in the opening. Or gauze should be packed between the incision in the liver and the tube. If it has not been possible to suture the liver to the parietes, gauze must be carefully packed round the tube to soak up any discharge that may escape by its side and to encourage the formation of adhesions to wall off the drainage track. In either event, the remainder of the parietal incision is closed by suture and in layers, if the condition of the patient admits; otherwise by through-and-through sutures of silkworm-gut

The transpleural route.—This is the most convenient method of approach for those abscesses which are situated on the upper surface of the liver and which so often raise the dome of the diaphragm The incision must be so placed that its centre will be directly over the abscess, so as to avoid reaching the latter by a long oblique track For instance, if the abscess is in the posterior part of the liver, the

incision may cross the posterior axillary line along the 9th or 10th rib, in the midaxillary line, the 8th or 9th, and in the anterior, the 7th or 8th. In many cases the diaphragm is so high that the lung is pushed out of the way and the two surfaces of the pleura are in close contact or even adherent. In any event, the surgeon must take great care not to separate the layers of the pleura. An incision 3 to 4 in. long is made in the line of the rib which is to be removed, and a rather lesser length of the rib is resected subperiosteally. The periosteum

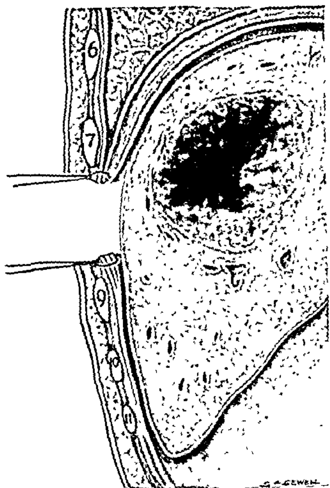


Fig. 375.—Transpleural approach to upper surface of liver.

The sutures uniting the costal to the diaphragmatic pleura are purposely shown long Traction on them steadies the diaphragm while this is being incised

on the deeper surface and the subpleural tissues lying beneath the rib are now incised along the same line without regard to whether the pleura is opened or not. One or two sutures of catgut on a rounded full-curve needle are now passed deeply, so as to attach the parietal pleural tissues to the diaphragm. (Fig. 375) The ends of the suture are purposely left long and drawn gently towards the surface, so as to prevent any separation of the pleural surface and to steady the diaphragm while being incised. The incision is now deepened in the same line and the pleura opened along the whole length exposed.

The upper pleural surface of the diaphragm will be recognized, as its muscular fibres can be plainly seen through its serous covering. If the pleural surfaces now tend to separate, one or two additional sutures of catgut are passed between the parietal tissues and the diaphragm in order to keep them in contact. The latter is then incised for a length of about 1½ in. A vessel will probably be divided and may require ligature. As soon as the under surface is reached, pus may be found, or there may be inflammatory adhesions, or the deeply congested liver may come into view. If necessary, the dome of the liver may be palpated, or needled, or examined in any way. In the absence of adhesions, a strand of gauze may be gently introduced between the lower cut margin of the diaphragm and the liver, so as to prevent escape of pus into the hepatic pouch. This step is usually unnecessary, as the liver seems to be pressed against the diaphragm either by the tension of the abdominal contents or by cohesion.

To open the abscess, a pair of sinus forceps is gently thrust into it, or a knife may first be required if it is evidently surrounded by a firm capsule, as sometimes occurs in the chronic varieties. The rubber tube of forefinger size must be in readiness, and is introduced into the cavity by the side of the forceps. It only requires to be long enough to reach well into the cavity and to project ½ in. beyond the skin. For better security, it should be fixed to both margins of the skin by a traversing silkworm stitch, and should also be furnished with a large safety-pin. As a rule, the tube will conveniently occupy the middle of the parietal incision, in which case the extremities of the latter should be drawn together by one or two silkworm sutures, passed deeply so as to include the structures down to the depth of the rib, but the skin must not be closed tightly round the tube.

When multiple abscesses are known to exist at the time of the operation, it may be possible to break down the walls between them from the cavity first opened, or they may be reached by independent incisions, or may be treated by aspiration. When they are discovered or develop during convalescence, the problem of their appropriate treatment will not be altered by the method of treatment of the existing abscess

The extra-serous route.—Attention was especially drawn to this method by Clairmont of Zurich.* It has been further developed by Alton Ochsner and others (1939) and has given good results. If the abscess is situated posteriorly, even if in the dome of the liver, it may be possible to reach it by the posterior extra-serous route Local or general anæsthesia may be employed. The patient is placed on the left side in the renal position and an incision made along the length of the 12th rib, which is excised subperiosteally. The pleura crosses the neck of this rib and may be in less danger if the neck is divided instead of disarticulated. An incision is then made across the bed of the rib, transversely outwards opposite the spine of the first lumbar vertebra, and is prolonged backwards to the edge of the erector spinæ (Fig. 376.)

* Acta Chir Scandinav, 1926, ix, 55

In this way the pleura is avoided. When the muscles are divided, the perinephric fascia is exposed and is displaced downwards with the kidney. The finger now enters the bed of cellular tissue between the upper pole of the kidney and the under surface of the diaphragm. By working upwards with the finger in the cellular tissue, the region of the abscess may often be reached and opened. Œdema indicates that pus is not far away As a rule the abscess can be reached by the finger, but it may be necessary to use an exploring needle followed by sinus forceps. If the abscess is high in the liver (Fig. 375), a tube used for drainage may be kinked in its rather long course to the level of the 12th rib. In these circumstances, multiple strands of gauze may be used instead of a tube. They are removed

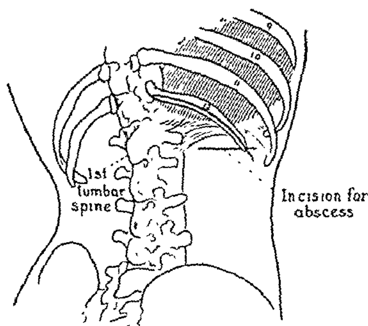


Fig. 376.—Extra-serous route for posterior sub-phrenic abscess.

one at a time over about a week. By the time all the strands are removed the track will be well established and a tube may be introduced if the amount of discharge seems to require it.

Operation in two stages.—This method can only very seldom be necessary, but if there is evidence that a liver abscess is infected with a virulent strain of pyogenic organisms, it may be considered wise to protect the peritoneum or the pleura before it is incised. The liver is exposed and the wound leading to the site of the abscess is packed with gauze, a small quantity being placed between the parietes and the surface of the organ to encourage adhesions The second stage should be deferred for as long as four days if possible, forty-eight hours being the minimum. After the gauze is removed, the liver may be incised or punctured and a tube introduced.

After-treatment.—The wound should be dressed with gauze soaked in a reliable antiseptic. A watery solution of 1 : 1,000 perchloride of

mercury is a reliable depot antiseptic for this purpose. While the discharge is copious the dressings must be frequently changed. Though it is desirable to remove the tube as early as possible, it must usually remain for seven to ten days, the time depending on the amount of discharge. It may, of course, be shortened during the interval, especially if it tends to be pushed out.

If the cavity is unusually slow in healing it may be gently irrigated with quinine (one drachm of quinine bihydrochloride to one pint of sterile water) which is an efficient antiseptic and may do good whatever the type of infection. Most of the complications are due to secondary infection, or are associated with the development of further abscesses either in the liver or elsewhere. Empyema is not an infrequent complication in the non-tropical variety. In the amœbic cases emetine must be continued, and steps taken to deal with the remaining bowel infection. Whenever possible, the patient should remain under observation for some time after the operation, as relapse sometimes occurs.

Results.—Published statistics give a mortality in tropical abscess of 14 4 per cent. as the result of treatment by emetine and aspiration.* In 1934 Ochsner and De Bakey† reported a mortality rate of 19 5 per cent. for open operation and 4·1 per cent. for conservative treatment, and Sir Leonard Rogers, writing in 1936,‡ is even more optimistic about the latter plan. When the combined treatment is better understood and more generally applied, this mortality will probably be greatly reduced.

It is fallacious to compare these results with the old statistics of the open operation, many of which date from the time before the value of emetine was understood In future the open operation will probably only be required in a more serious type of case which has not responded to other methods, and the operative mortality may possibly be higher, but with a proper technique and the necessary care to prevent secondary infection, very good results may be anticipated. Recrudescence of liver abscess may occur even years after successful treatment and when the patient has left the tropics

In abscesses not due to the amœba the condition is much more serious. The mortality, which is high, depends largely on the causative factor, the organism concerned and the number of abscesses. The use of penicillin and the antibiotics may be expected to improve the results.

OPERATIONS FOR HYDATID

Hydatids may be found in any part of the liver, but much more frequently in the right lobe Broadly speaking, they may grow mainly upwards towards the dome or mainly downwards towards the abdomen. In parts of the world where this disease is frequent, it is often recognized with considerable accuracy, both in its nature and exact position,

* Sir Leonard Rogers, *Lancet*, March 11 and 25, 1922, i, 463
† *American Journal of Digestive Diseases and Nutrition* 1935, ii 47
‡ *British Encyclopædia of Medical Practice*, vol. I, p 375

but in Great Britain it is more often discovered accidentally, and especially when some complication such as suppuration occurs in a cyst of moderate size and first draws attention to its presence. Hydatids are multiple in 60 per cent. of cases, not only in the same organ, but in different parts of the body. Before any contemplated operation it is therefore important to make a most careful examination with this possibility in view. The X-ray is a valuable help, and will sometimes show both cysts and daughter-cysts.

Indications.—As yet there is no method known by which hydatids can be killed *in situ* and as they tend to grow and to disseminate, their presence is an indication for treatment. But complicated problems may be involved, and each case must be considered on its merits. Pain or tenderness; rapid increase in size; the association of pleurisy or jaundice or symptoms suggesting suppuration are all indications for early surgical interference.

Choice of operation.—Open operation has, for the time being, superseded all other methods of treatment, but where there are multiple hydatids, aspiration, followed by the injection of 1 per cent. formalin, may be considered. The principle underlying all the operative methods is the thorough and complete removal of the parasite (true cyst), without contamination of the surrounding parts. The treatment of the adventitious capsule (false cyst) admits of much variation. The methods in vogue at the present time are:—

1. Removal of parasite, filling the cavity with saline and complete closure—Harold Dew.
2. Removal of the parasite with free drainage of the adventitious capsule—*marsupialization*.
3. Removal of the parasite and as much of the adventitious capsule as possible, with obliteration of what remains by suture, and closure of the abdominal wall without drainage—*capitonnage*.
4. Removal or enucleation of the whole cyst together with its adventitious capsule—*excision*.

Except as a temporary measure for the relief of urgent distress, incision and drainage alone, i.e. without removal of the parasite, must never be employed. The correct operation suited to each case can only be determined after the cyst has been explored but, though excision is ideal, marsupialization is probably the best method in the great majority of cases

General technique.—General anæsthesia should be employed, as with local there is a definite risk of anaphylatic shock. The surgeon must not be hampered by too short incisions and, except where suppuration is obvious, an ample exposure is necessary. There must be no idea of simply cutting rapidly down on to the most prominent part of the swelling and carrying out some dramatic intervention. The most direct incision will generally be the right one, and it is usually best made over the most prominent part of the swelling. The exact

incision will depend upon the position of the cyst, and this must previously be determined by clinical and radiological investigation. In the majority of cases an anterior para-median or trans-rectus incision answers very well, though for smaller cysts the oblique subcostal incision of Kocher may be better. When the cyst is situated in the dome of the liver the transpleural or posterior extra-serous approach should be employed (pp. 884, 886).

The cysts are often multiple and, when there are no contra-indications such as suppuration or extensive adhesions, the first step after opening the abdomen should be to palpate both lobes and both surfaces of the liver. As a rule only one cyst should be dealt with at a time, but this partly depends on the size and relative position. In all hydatids, it must never be forgotten that the fluid will almost certainly contain active elements which, if they escape into the peritoneal cavity or soil the wound, may give rise to secondary hydatids with all their attendant possibilities. When the incision has been made down to the hydatid, the first step is to protect the wound and the peritoneal cavity by careful packing with gauze. Professor Dew, of Sydney, whose experience in the surgery of hydatid diseases is unrivalled, suggests that the superficial layer of gauze should be black because it is so much easier to detect hydatid membrane or tiny hydatids against this background. When the gauze has been suitably arranged, it should be thoroughly moistened with 2 per cent. formalin solution This will be taken up by the gauze and will act as a sterilizing agent for the infective material. If some of the formalin does soak through the gauze, even into the peritoneal cavity, it does not appear to do much harm and its value certainly outweighs this possible disadvantage. If the hydatid is found lax, a couple of sutures of catgut or silk may be introduced into the adventitia on either side of the proposed incision. These should be used to act as guys to prevent unexpected retraction of the cyst, and also to draw the cyst up into the wound during evacuation If, on the other hand, the cyst is very tense, it is better to omit the guys until the tension has been reduced by evacuation of some of the contents. While this process is taking place the cyst is kept against the wound by the pressure of the hands of an assistant on the neighbouring abdominal wall. A fine aspiration needle is introduced and enough fluid withdrawn to reduce the tension The way the fluid escapes is some little guide to the type of hydatid. If it flows freely and in quantity the cyst is probably univesicular, but if only a small amount escapes it probably means that there are daughter cysts and this is confirmed if more fluid is withdrawn when the needle is thrust farther After as much fluid as practicable has escaped an effort is made to kill any free hydatid elements by injecting full strength commercial formalin into the cyst through the same needle. About 5 c.c. for a cyst of a diameter of 10 cm is a suitable quantity With the needle still *in situ*, the surgeon waits for from five to ten minutes in the expectation that the formalin will diffuse among the remaining fluid and will help to kill the parasite After this process of formalization,

the hydatid should be incised sufficiently to admit the nozzle of a suction apparatus which should have a bore of about 15 mm. With such an apparatus, the wall of the mother cyst may be sucked into the instrument, or may be drawn into the nozzle and imprisoned and can then be withdrawn. Small daughter cysts will very readily traverse the trocar and will be found in the reservoir. Having removed as much as possible by this means, the surgeon must satisfy himself that all the secondary cysts and the whole of the lining membrane have been withdrawn. A long sponge handle is a very useful instrument for getting hold of considerable portions of membrane, while smaller pieces or tiny cysts may be entangled in dry gauze used with the sponge handle and gently rotated inside the cyst. Whenever possible, the interior of the adventitia should be inspected in order to be sure that the whole of the débris has been removed; for this purpose a strong headlight is very helpful. When the surgeon is assured that all the parasites have been removed, the interior should again be swabbed with 2 per cent. formalin. Redundant adventitia may then safely be cut away but the temptation *to try to remove the whole of the ectocyst must be resisted.*

The stage has now arrived at which the surgeon must decide how to complete the operation, that is to say, whether one of the closure methods is to be employed or whether the cavity should be drained. *If the cyst is obviously infected—which will be indicated not only by* the character of the fluid but by its odour—or if it is incompletely emptied, or if the fluid contents are stained with bile, then drainage is the only safe method. In fact, it may be said that for those who only have to deal with hydatids occasionally it is a sound rule to drain when in doubt. The alternative plans available are:—

Method 1.—After removal of the parasite the adventitious cavity is filled with saline, completely closed by suture and returned to the abdomen, which is closed without drainage. If there is doubt about the secure closure of the adventitia a tube should be brought from the neighbourhood of the site of closure through the parietes to the surface.

Method 2.—This may be looked upon as the routine operation, and is the one most generally practised by surgeons who have a wide experience of hydatid disease. The steps are (1) exposure of the cyst, (2) confirmatory puncture followed by formalinization, incision and extra-abdominal delivery of the lax part of the cyst, (3) removal of the parasite, (4) marsupialization of the adventitia.

After the cyst has been emptied by removal of the parasite, as already described, the edges of the incision in the adventitia are fixed with a continuous stitch to the peritoneum and muscle of the abdominal incision, and a thumb-sized rubber drainage-tube is brought from the cavity. If there is much oozing of blood the tube may be packed round with gauze. In most cases recovery is rapid and complete. Should it be necessary to reach the dome of the liver, access is obtained either by the posterior subserous route or the transpleural route after resection of a portion of rib, as described in the section on liver abscess (p. 884).

In order to diminish the undoubted risk of infection of the pleural cavity by hydatid fluid Dew advises a two-stage operation in non-urgent cases. Two or three weeks should be allowed to elapse between the stages. The edges of the orifice in the adventitious cyst and the diaphragm should be fixed together by suture and, if the diaphragm is not already attached to the parietes, the ends of these sutures should be used to fix it. Recovery is equally satisfactory by this method.

Method 3.—This method aims at the obliteration of the adventitious cyst by suture, in order to do away with the necessity for drainage. It can only be successfully employed when the cavity is of moderate size, as it is necessary to reach to its depths to introduce the sutures. The earlier steps are the same as have just been described. *After the thorough removal of the parasite and the swabbing out of the cavity*, as much of the adventitious cyst as can easily be dealt with is cut away. The walls of the remaining cavity are then drawn together by a superimposed series of catgut sutures passed around the cavity, commencing near the bottom and applied at just such an interval as will ensure apposition of the walls without pocketing. Finally, the edges of the incision in the liver are drawn together. It is always wise to bring a small drainage-tube or rubber tissue drain through the abdominal wall from the neighbourhood of the last suture. This is merely a safeguard, in case there is a leakage of bile, but the drain should not be removed until the abdominal incision is first dressed, on the ninth or tenth day.

Method 4.—Complete excision or enucleation of the unopened hydatid together with its adventitia is certainly an ideal proceeding, but it can seldom be safely carried out in actual practice. It is quite different when an organ like the spleen or a kidney is the seat of the parasite. Pedunculated hydatids sometimes lend themselves to this plan, but in other circumstances the proceeding is likely to be as dangerous as it is unnecessary. However prominent the cyst may be, some part of it is almost always deeply situated in the liver substance, and its removal in this way entails grave risk of hæmorrhage and of biliary fistula. When it can be carried out the area of the liver from which the cyst has been removed must be closed by sutures, and if this cannot be done it will have to be in part obliterated and the remainder packed with gauze. Except in the simplest cases the operation is not justified.

Combined operations.—These may be required in certain cases. When the hydatid is very large it may be possible to cut away a considerable part of the adventitious cyst, the remainder being marsupialized; thus the cavity is diminished and the period of drainage shortened. On the other hand, the cavity may be so large and extend so far back that a second and posterior opening for drainage is an advantage.

Multiple cysts are to be suspected if the cyst does not yield as much fluid as might have been expected from its size, or if the main swelling does not diminish after evacuation. If possible, they should be treated

by opening one cyst from another, but in each the parasite must be removed if the operation is to be curative. Sometimes each cyst must be dealt with separately, and this may necessitate independent parietal incisions or even repeated operations. Very often the treatment of one cyst encourages a second and perhaps unsuspected hydatid to enlarge rapidly and grow forward, demanding another operation soon after the first.

Operation in two stages is only required if the cyst is so situated that it appears as though it would be impossible to bring it forward to the abdominal incision, even after evacuation. When this method must be adopted, an attempt should be made to get some part of the liver near the cyst attached to the parietes, and gauze soaked in 2 per cent. formalin (with any excess squeezed out) is then packed down in contact with the cyst, so as to make a track, surrounded by a rampart of adhesions, from it to the surface. A week or ten days later the gauze is removed under anæsthesia and the operation completed.

In **suppurating cases** when the liver is enlarged downwards, a transverse or oblique incision carried back into the right loin is eminently suitable, as it greatly facilitates drainage. The posterior subserous exposure may be most suitable for those in the back part of the liver. There is often some peritonitis over the cyst, and there may be adhesions, but if not the peritoneum must be carefully packed off before the cyst is opened, because it is usually impossible to bring the latter out of the incision when thickened by inflammation. In spite of infection, it is most important to be sure that the whole of the mother-cyst and any daughter-cysts are removed, for suppuration cannot be relied upon to kill them. In these and all similar operations a head-light may be very useful.

In **ruptured cyst**, immediate laparatomy is the proper course. The escaped effusion must be mopped out of the peritoneal cavity and the primary cyst treated by the method which seems best suited to its situation. If possible, the point of perforation should be made the drainage opening. Cases in which *rupture occurs into the viscera* are sometimes cured spontaneously, and hence the surgeon should not hastily interfere. When the biliary apparatus is involved, secondary cysts may be impacted in the common duct, and may have to be dealt with like gall-stones in the same situation. If cysts which have burst into the hollow viscera are opened a fistula may result, and may necessitate the separation of the cyst from the viscus in order that the perforations in the latter may be dealt with by suture.

Incidental removal of hydatids.—Every now and again small hydatids are unexpectedly discovered in the liver in the course of some other operation. Their walls are usually calcified. If they do not obviously bear a relation to the symptoms for which the operation has been undertaken, they are best left alone, unless they are in such a position that they may produce injurious pressure on the bile-ducts, or unless there is definite evidence of activity, as shown by associated trouble.

They can often be enucleated entire, but this is not always so simple as it looks, and there may be a good deal of hæmorrhage from the bed in which they lie, which may have to be dealt with by deep sutures or by gauze packing.

After-treatment.—Great care must be taken to avoid secondary infection, but this should present no difficulty if reliable antiseptic dressings are applied next the wound and are frequently changed, with proper precautions, as long as the discharge is abundant. The tube can usually be safely removed in a week or ten days. The amount of discharge must be the guide, but the tube should be dispensed with as soon as possible. Suppurating cases may require a longer period of drainage, but in them the tube must be shortened until it is just sufficiently long to reach into the cavity. If the discharge is slow in diminishing, advantage should be taken of gravity, and the surgeon must see that the patient lies for the greater part of each day with the opening dependent. In some such cases a second incision may be required to ensure drainage in the most suitable situation.

Complications.—Mild anaphylactic symptoms—e.g. cutaneous eruptions, dyspnœa and asthma-like attacks—may appear after some days, but usually disappear spontaneously, without treatment. High temperature, with or without rigors, usually means infection. The surgeon must at once make sure that the tube is draining freely; for fragments of hydatid membrane may block it. Fever which does not abate when free drainage is renewed may be due to sub-phrenic abscess, empyema or even cholangitis. When it is associated with increasing jaundice, the common duct must usually be drained. In such cases the prognosis is grave. Persistent sinus may be due to (*a*) a portion of hydatid left behind or regrown, (*b*) failure of the adventitious capsule to contract, (*c*) calcareous plates in the wall of the adventitia, (*d*) an unabsorbed suture or even a lost drainage-tube, (*e*) a communication with one of the larger bile-channels. A gentle exploration with forceps may succeed in withdrawing fragments of hydatid membrane. Care must be taken to see that the external opening is sufficiently large and patent, and for this purpose a big self-retaining catheter is useful. An X-ray photograph may be helpful in determining the cause. If after three months the sinus remains unhealed, it should be explored under anæsthesia. If no cause is found, an independent opening may be considered necessary. A mere track may be treated by Beck's bismuth paste, but if there is any communication with the bile-ducts, this method is not without danger.

Results.—Apart from the complicated cases, the results are very good. MacLaurin, of Sydney, in a series of 70 cases, had 7 deaths, of which 3 occurred among 4 cases operated upon for rupture of the cyst, 2 among 19 cases operated on for suppuration, and 2 cases otherwise complicated. That is to say, no simple case died. These figures refer to the operation of marsupialization, and reflect the experience of others who employ this method. Harold Dew, also of Sydney, points

out (1939) that the mortality largely depends on complications. In suppurative cases it approached 20 per cent. and with intra-pleural or intravisceral rupture about 50 per cent. The published statistics of the treatment by resection showed a mortality of only about 9 per cent. This low figure is misleading, because this operation can only be done in selected cases and is probably only undertaken by those specially skilled, whereas marsupialization is the method most commonly employed for every type of case, including all kinds of complication, and often by surgeons without any special experience.



Fig. 377.—Portion of liver occupied by large hepatoma.
The mass, weighing 2 lb. 3 oz., was successfully excised from a boy of 13, who was alive and well fourteen years later.

With better recognition, earlier treatment and fewer complications, and the help of the newer antiseptics and other advantages, the general results at the present time (1950) are much improved. In a personal communication the latter author expresses the opinion that the general mortality will soon be only about 5 per cent. and in the uncomplicated clean liver case probably nearer 2 per cent.

Late results.—In many cases successfully operated upon, further cysts develop. This may be due (*a*) to the growth of cysts already present but not detected at the time of the primary operation, (*b*) to infection from the fluid during operation, (*c*) to the re-infection of the

patient. The development of other hydatids may be delayed for long periods (in some cases twelve years), and it may be that the scolices have remained latent.

Operation for Non-parasitic Cysts

In several reported cases the cysts have been pedunculated, and it has been possible to excise them safely but those buried in the liver are more common and may contain many pints of fluid. Those situated in the substance of the liver must be treated as for hydatids, usually by partial removal of redundant wall and marsupialization of the remainder. Multiple cystic disease of the organ is usually associated with a similar condition in the kidneys and pancreas, and is unsuitable for surgical intervention.

PARTIAL RESECTION OF THE LIVER

This may be a very simple or a most formidable undertaking, depend- upon whether the area to be dealt with is pedunculated or otherwise. Though there are many conditions in which resection of the liver may be looked upon as a legitimate surgical undertaking, none of these occur frequently, but as they may be met with unexpectedly, it behoves the surgeon to be prepared to undertake this operation at any time.

Indications. (1) Simple tumours.—Those usually found are angiomata, and may be enormous (Symmers and Ward-McQuaid, 1950*) or solid adenomata. Some of the latter suggest malignant tumours of epithelial type, and are known as hepatomata (Fig. 377.) Both types of tumour may be quite localized, and are often found in a pedunculated area or near the margin of the liver, with a tendency to become pedunculated.

(2) Simple cysts and hydatids.—These are only suitable for resection when definitely pedunculated. Sometimes the connection with the liver is narrow and tongue-shaped.

(3) Malignant new growths, such as primary sarcoma, primary carcinoma, and some few cases of secondary carcinoma, can be resected if a sufficient margin of healthy tissue can be taken away (Brunschwig†); otherwise the operation is valueless. The entire left lobe containing metastatic deposits secondary to an operable primary growth in the rectum has more than once been removed with some temporary success Lloyd-Davies'‡ patient died 2½ years later from intestinal obstruction due to Meckel's diverticulum. At a post-mortem there was no malignant growth in the liver or elsewhere.

(4) As part of the operation for excision of malignant gall-bladder.—Some surgeons hold that whenever the gall-bladder is removed for cancer, a wedge-shaped portion of the liver should also be excised. Others are content to reserve this excision for cases in which the liver is involved by direct extension. The after-history of cases of operation

* Symmers and Ward-McQuaid, *Brit Journ Surg*, vol 38, p 12, July, 1950
† University of Chicago Press, 1947, and *J Am Med Assoc*, Jan 3, 1948, p 136
‡ *Proc. Roy Soc Med.*, 1947, xl, 875

for malignant disease of the gall-bladder shows that, when this condition can be recognized by the naked eye, no operative treatment, whatever the type, can be expected to bring about permanent cure, and therefore, unless there are some very special reasons, it is not justifiable to incur the undoubted additional risk which resection of a portion of liver involves.

(5) **For direct extension of malignant disease from the stomach or colon.**—Usually only a portion of the edge of the liver is invaded, and the surgeon can often deal with this by a comparatively simple extension of the primary operation.

(6) **For the removal of Riedel's lobe.**—The mere presence of this lobe is not in itself an indication for its excision, but removal may be required when it causes symptoms such as persistent dragging or pain, or when it has become an obsession to the patient. The actual decision whether the lobe should be excised can only be made after the abdomen is opened, and the surgeon must then satisfy himself that the anomaly has been the cause of the symptoms complained of, and, further, that it can be removed without undue risk. In many cases the symptoms are associated with disease in the gall-bladder which can be dealt with effectively without interfering with the lobe.

(7) **For some granulomata.**—Many operations for excision of portions of the liver have been carried out under the supposition that a neoplasm was being dealt with, but subsequent examination has proved that the condition was syphilitic. Curiously enough, the gummatous condition has often involved only a limited area, thus further leading to confusion with neoplasm. Gummata are usually smaller than malignant nodules, their surface is rounded and not umbilicated, and there is more perihepatitis. If the surgeon can recognize the condition as being of this nature at the time of the operation, there is no justification for carrying out excision If real doubt exists, it would be better to remove a piece for section and to perform a secondary operation if needful The absorption of a localized gumma may be greatly hastened by scooping out its softened centre, and this may safely be done if the patient has already been properly treated for syphilis without result.

Choice of operation.—The method can only be determined after the abdomen has been opened and the parts have been explored. The ideal plan is to remove the growth and to repair the wound in the liver by suture. Formerly it was a question of whether the tumour was sufficiently pedunculated to be brought outside the abdomen and the pedicle treated extraperitoneally. This method is now seldom, if ever, employed, but it should be borne in mind, for it can sometimes be used with success. The indications for its use may be (*a*) a well-pedunculated tumour with a very vascular pedicle such as is found in some of the angiomata, or (*b*) the inexperience of the operator. The tumour is brought outside the abdomen and the pedicle transfixed by two stout needles, Wyeth's pins or thick knitting-needles will serve

the purpose. An elastic ligature (such as a piece of fine rubber drainage-tube) is then wound tightly round the pedicle on the proximal side of the needles and the abdominal wall sutured. The needles lie on the abdominal wall, pads of gauze intervening. As a last step, the tumour is cut away either by knife or diathermy and the stump is dressed antiseptically. In about a fortnight the pedicle will have become firmly adherent to the parietes, and the process of its isolation will be well advanced, so that the needles can safely be removed, but it is usually many weeks before the stump shrivels up and heals over.

Technique.—The technique presents three problems—(1) The control of hæmorrhage during the operation, (2) the permanent arrest of hæmorrhage and (3) the treatment of the liver wounds.

If the tumour is pedunculated, a clamp may be applied to its base. The best variety is a stomach clamp with longitudinal grooves and a

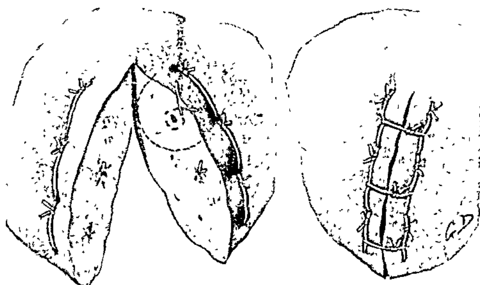


Fig. 378.—Diagrammatic representation of method of liver hæmostasis and suture. Cf Fig 315, p 764.

good bow. If such a clamp is slowly applied it may prove efficient without damaging the liver. In some cases it may be possible to use an elastic ligature as a tourniquet, and some surgeons pass such a ligature through the liver and tie it on the proximal side of the proposed incision.

When the tumour is sessile and the line of incision must penetrate far into the liver substance, the clamp can sometimes be effectually used if the liver is not too thick, or the organ can be held and compressed on either side of the proposed incision by the hands of an assistant. As the liver is divided clamps may slip, and the hands of an assistant are often in the way; therefore it is better not to rely on these methods, but to pass a series of sutures through the liver substance, parallel with the line of the proposed incision and about ½ in. from it, by the method shown in Fig. 378. The sutures of catgut

(No. 3 or 5) can be passed with a large curved intestinal needle, or right through the liver with a straight needle, and tied as shown.

In any event, it is necessary to make the actual incision into the liver substance slowly, so that any bleeding can be arrested as the excision proceeds. The branches of the hepatic artery can be caught in forceps and tied. Large venous trunks may be surrounded by ligature with a round needle; this is tied very gently, as there is a risk that it may cut its way out and fail in its purpose. After the excision is made, apposition of the two cut surfaces suffices to stay most of the bleeding, as the blood-pressure is so low; but it is not always possible to bring the surfaces together, even when the excision is in the form of a wedge. Whatever method is employed, any area that bleeds after the edges have been brought together must be controlled by an additional suture here and there or by little plugs of hæmostatic gauze. In some cases the excision has been made with the cautery or with the diathermy knife, but these methods are slow and, as a means of arresting hæmorrhage, very uncertain. In dealing with the actual case the various steps required are as follows:—

1. Adequate exposure.
2. Exploration and decision on the method of removal.
3. Temporary control of hæmorrhage.
4. The actual excision of the involved area.
5. Permanent arrest of hæmorrhage and repair of the liver wound.
6. Toilet of the peritoneum and closure of the abdominal incision.

The parietal incision will depend on the situation of the tumour and the build of the patient. The exposure must be adequate, and for most cases some type of vertical incision will suffice, but the surgeon must never hesitate to make a cross cut if additional room is required. If the tumour is far back on the right lobe, then a long oblique incision an inch below the costal margin will be the best. It may be possible to obtain much help in the exposure from the reverse Trendelenburg posture, the elevation of the lumbar region, and the division of the triangular ligament. As soon as the abdomen is opened the condition must be carefully explored to determine the feasibility of removal. For this purpose adherent omentum may have to be separated or adhesions to the parietes and the other viscera divided. This may be done without hesitation, for some of the most favourable cases are associated with such adhesions, and their separation may bring an apparently hopeless condition within the range of safe surgical enterprise. The adhesions may be very vascular and unless they can be ligatured are best severed with the diathermy needle. If there is any question of malignancy, a careful search must be made, on the one hand for a primary focus, and on the other, for further deposits in the liver. (In illustration of the latter are the not uncommon cases of malignant gall-bladder with direct extension to the liver, which could easily be removed by a moderate wedge-shaped excision, but in which a secondary deposit elsewhere in the liver renders excision valueless.) It is most important to determine the relation of the tumour

to the hilum and the incisions that will be necessary for its removal, as this part of the liver must not be encroached upon. The gall-bladder and cystic duct can of course be removed, if necessary. Whenever possible, the part to be incised should take the form of a V, but to avoid going too near the hilum it may be necessary to leave the point of the V rounded or rectangular. When the part removed is not too large, the gap can be brought together by suture, but if this is not possible the apex may be dealt with in this way and the remainder left gaping. In order to bring the edges of the V-shaped gap together, sutures of strong catgut are passed over the hæmostatic sutures previously introduced. (Figs. 378, 379.) The method is difficult to describe, but ought to be easily understood from the figures. If the sides of the liver wound cannot be approximated, then either the cut

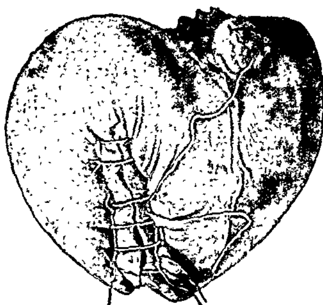


Fig 379 —Drawing of a specimen illustrating method of liver hæmostasis and suture completed

surfaces may be folded on themselves by interrupted sutures, or the gap left open when the surgeon is satisfied that the main hæmorrhage has been controlled. Every effort should be made to stay oozing, a good deal of which may be due to venous engorgement, which will stop when the liver is allowed to fall back into position. Omentum packed into the space and fixed by a suture may help to arrest oozing or it may be controlled with absorbable gauze. In spite of great care, it may be necessary to leave in a strand of ordinary gauze, and, in order to exert pressure on the bleeding area, one or two sutures may be passed through the liver on either side, so that the edges of the gap may be drawn together over the gauze. It will not be possible to remove the gauze with safety sooner than 10 to 12 days after operation. In all cases drainage should be provided, lest there be bile leakage.

After-treatment.—This is exactly similar to that described for cases of injury to the liver.

Results.—In recorded cases the immediate mortality, about 15 per cent., has not been so high as might be expected, probably because this operation is only essayed by practised surgeons and after most careful consideration. The remote results depend on the condition demanding excision. Very large portions of the liver can be removed without interfering with the health and well-being of the patient (the portion shown in Fig. 377 weighed 2 lb. 3 oz.), and permanent recovery may be expected to follow operation for cysts and simple tumours. In malignant disease early recurrence has so far been the rule, though with one or two notable exceptions.

OPERATIONS FOR CIRRHOSIS OF THE LIVER

The Mayos have carried out splenectomy in some cases of cirrhosis, on the assumption that this condition may depend on metabolic poisons which are elaborated in the spleen. Several plans have been devised for the relief of the ascites.* Most of the operations are based on that devised and introduced by Drummond and Morison† in England, and independently by Talma and van der Meulen in Holland. To Rutherford Morison belongs the credit of establishing the operation on a secure footing, and of publishing in 1895 the first successful case. The object of the operation is to *form new vascular communications between the parietal and portal venous systems*, and in that way to aid the abdominal circulation and relieve the embarrassed portal vessels. An endeavour is made to bring this about by vigorously scrubbing the surface of the liver and spleen and the adjoining parietal peritoneum in the hope of setting up adhesions, and by suturing the omentum to the abdominal wall.

Indications.—Drummond and Morison advised that their operation should be reserved for ascites resulting from alcoholic cirrhosis, and they stipulated that the patients selected should be free from cardiac or renal disease and should have withstood several tappings. When these rather rigid indications have been observed the results have been very satisfactory. In other types of ascites, often of undetermined origin, the results have not been so favourable, but there is no reason why the operation should not be tried when other methods have failed. Success is not to be expected, whatever the primary cause, unless the ascites is mechanical and not merely toxic, nor if the patient is already suffering from cholæmic symptoms. For Banti's disease with ascites omentopexy should be combined with splenectomy and has contributed to the not infrequent successes.

Choice of operation.—The after-histories of patients treated by the Drummond-Morison operation have been sufficiently satisfactory to

* Of *recent* years trial has again been made of Portocaval anastomosis (Eck's fistula) or some other plan of direct union between the portal venous system and the systemic veins as a means of relieving portal hypertension resulting from liver cirrhosis. Conclusive long term results are not yet available. (*See* p. 904.)

† *Brit. Med. Journ.*, Sept. 19, 1896, ii, 728.

justify its continued use in properly selected cases. Attempts have been made to treat ascites by peritoneal drainage into the cellular tissue of the thigh through the femoral opening* or into the subcutaneous tissues of the abdominal wall (Paterson), and these operations have been attended by a certain measure of success. They have the advantage of being simpler than omentopexy, and can therefore be carried out with little risk in debilitated subjects. There is the further point that, *if not successful, there is nothing* to prevent subsequent performance of the complete operation of Drummond and Morison.

Preparation.—Improvement often follows medical management and dietetic *regimen. Fat intake is reduced to a minimum,* proteins are increased and the calorific value made up by carbo-hydrates. Vitamin intake should be increased, especially A, D, K, and B complex. Fluids *must be restricted. These patients* are often bad risks, and a week or two should be spent in preparation. They should be kept in bed so that they get accustomed to lying on their backs. Bowel action should be free, and efforts made to overcome distension. Digitalis, nux *vomica, or strychnine should be substituted for the* accustomed stimulants. The abdomen should be retapped about four days before the intended interference.

Technique.—*It is difficult to perform the complete operation properly* without a general anæsthetic. The original operation devised by Drummond and Morison comprised three definite steps:

1. An attempt to promote the formation of adhesions between the liver and spleen and the parietes.
2. Fixation of the omentum to the abdominal wall.
3. Drainage of the peritoneal cavity.

The incision is a median one from the ensiform to within an inch or so of the umbilicus. The peritoneum is actually opened to the left of the middle line in order to avoid the round ligament of the liver with its enlarged veins, and the incision stops short of the umbilicus with a view to avoiding injury to the caput medusæ. On opening the peritoneal cavity the first step is to inspect the liver, in order to verify the diagnosis. This done, a small independent opening is made just above the pubes, and a Keith's glass tube is introduced into Douglas's pouch, where it remains. Any fluid which does not escape in this way is soaked up in mops or removed with the suction apparatus. The escape of the fluid and the inspection of the viscera are facilitated by the reversed Trendelenburg position. As soon as the fluid is removed, the surfaces of the liver and spleen and the adjoining parietes are roughly scrubbed with gauze with the deliberate object of injuring the endothelial covering, thus encouraging adhesions The omentum is then fixed to the posterior surface of the abdominal wall about 3 in on either side of the midline incision, and again about the same distance below the umbilicus. This is best done by silkworm-gut sutures passed through the abdominal wall and tied *outside over gauze* dossils

* W. E Wynter, *Arch Middx Hosp*, July, 1909, xi, 15, *Clin Series*, and Sampson Handley, *Brit Med Journ*, April 16, 1910, i, 922.

(Fig. 378.) The omentum is also caught and sutured to the peritoneum during the closure of the incision, which is to be done with care, as ventral hernia has often been an unpleasant sequel. As a last step, the abdomen is carefully strapped and firmly bandaged *from above downwards* in order to keep the parietes and viscera in contact.

After-treatment.—From the first, the patient must be kept propped up in bed to encourage all fluid to gravitate to the pelvis. The most important consideration is to guard against sepsis. Antiseptic measures must be employed, and the gauze around the tube and covering it, as well as the syringe for withdrawing the fluid, should be kept in a solution of perchloride of mercury 1 : 1,000. The gauze round about the tube will soak up some fluid, and should be changed when soiled. The fluid which accumulates in the pelvis must be withdrawn, at first every hour, and subsequently at increasing intervals. It soon diminishes so much that only half an ounce or so can be withdrawn by the syringe every four hours. When this stage arrives, it is sufficient to apply antiseptic gauze over the mouth of the tube and to change it as often as it becomes soiled. The glass tube should be rotated twice daily to prevent omentum getting entangled in the holes and to release any masses of lymph which may block them. A rubber tube may be substituted for the glass one about the fourth day ; one that will just easily occupy the lumen of the Keith's tube is slipped into the latter, which is then removed. After the substitution of the tubes, the patient may be moved in bed more freely. All drainage can be dispensed with about the tenth day.

The greatest danger is from failure of liver function and resulting cholæmia, which may come on about the second to the fourth days; this is guarded against by early and free purgation and by abundance of liquid by the mouth and the intravenous injection of 5 per cent. glucose solution or, if response is tardy, blood transfusion. As soon as the risk is over, the amount of liquid taken should be diminished as much as possible The management may be difficult and complicated and the assistance of an experienced physician is valuable and comforting. There is some risk of pulmonary complications, and the patient should be encouraged to take deep breaths and to cough systematically. Unless there has been some leakage of fluid through the median incision, this need not be dressed until the twenty-first day, when the omental fixation sutures may be removed. At the end of a month the patient may leave bed, but the upper abdomen should be kept firmly bandaged for some weeks. There is usually some re-accumulation of fluid, but it is often reabsorbed, and this process may be encouraged by inunctions of stimulating ointments such as mercury or capsicum, though it may be necessary to tap the abdomen once or twice.

It is essential that the patient should abstain entirely from all alcoholic liquors if the operation is to be permanently successful.

Complications.—Ventral hernia has occurred in several of these cases, and may be very troublesome. Operations for the radical cure of

such hernias have proved dangerous, as there is a tendency to cholæmia for some time after the operation. The abdominal wall is also unusually vascular as the result of the venous engorgement. Some of the male patients have complained very much of inguinal hernia, which has usually been present before the operation, but has been overshadowed by the more troublesome ascites. The fact that such patients are anxious for radical cure is perhaps an evidence of the increasing self-respect which results from their restored health.

Results.—The immediate mortality in suitable selected cases is about 15 per cent., and symptomatic cures have been obtained in about 40 per cent. of the cases. Recurrence of the ascites may follow a return to alcoholic habits, but secondary cure may again take place after suitable treatment.* Two patients who were rapidly going downhill in spite of careful treatment and repeated tapping are known by me to have been alive and perfectly well thirteen and thirty-four years† after operation.

Modifications.—The most important is the omission of the drainage-tube. This much simplifies the after-treatment, but the fluid often re-accumulates at first and the abdomen may have to be tapped several times in the first few weeks or months after the operation. Some operators fix the liver edge to the parietes by suture rather than rely on the possible formation of adhesions. Occasionally the omentum is shrivelled up and lies close along the colon, leaving no "apron" for fixation to the abdominal wall. In these circumstances the transverse colon should be stitched to the parietes. Schiassi raised a flap in the abdominal wall and fixed the omentum and spleen into a space made between the posterior surface of the muscles and the peritoneum, whereas Mayo introduced a portion of the omentum into a pocket made by separating the posterior sheath of the rectus from its muscle. Narath's method aimed at combining subcutaneous drainage with the formation of new vascular channels, and for this purpose he introduced the omentum into the subcutaneous tissue of the abdominal wall.

Other methods. Porto-Caval anastomosis.—As long ago as 1877 the physiologist Eck working on animals established a direct communication between the portal vein and vena cava in connection with studies on liver function. Later this idea was seized on by the French physician Vidal in the hope that it would provide a satisfactory means of by-passing the liver in cases of intractable cirrhosis. At that time the results were very unsatisfactory and most, if not all, of the patients on which it was tried died But the underlying idea of Eck has always been in the minds of surgeons and in 1945 was revived by Blakemore and Lord‡ and by Whipple§ for the relief of portal hypertension and its consequences, especially hæmatemesis from œsophageal varix and to a lesser extent ascites, and in the hope of arresting the cirrhosis.

The method they employed was to make an anastomosis between a large portal radicle like the splenic and a major systemic vein like the

* Sinclair White, *Brit. Med Journ*, 1906, ii, 1287
† *Brit Med Journ* 1940, i, 745.
‡ *Surg Gyn and Obst.*, 1945, 84
§ *Anns Surg*, 1945, cxxii, 449

renal. Such an anastomosis was calculated to by-pass about 40 per cent. of the portal blood. To bring this junction about it is usually necessary to remove both spleen and left kidney so that a direct anastomosis can be made between the end of the divided splenic and the renal veins. These workers devised a technique which simplified the union and have employed the method in many cases with encouraging success.* Attacks of mental confusion have recently been reported after the operation.† The technique of this vessel anastomosis is described at page 553 in the section on Vascular Surgery.

There is rather a tendency to return to the original method of Eck.‡ This method by-passes a greater volume of the portal blood and is less likely to become obstructed than when smaller veins are employed. A special clamp which has been introduced has helped to simplify the technique. A number of patients have been benefited, the hæmatemesis has ceased and to a lesser extent ascites has disappeared and the general well-being has greatly improved. But the whole plan requires a most careful appraisal of all the circumstances and many preliminary investigations are necessary. Close co-operation with internists is essential.§

MISCELLANEOUS OPERATIONS

Direct incision of the liver may be required to inspect its cut surface, or for biopsy. When possible, it is best to select some part of the border of the liver, and the incision should be wedge-shaped. Hæmorrhage can be controlled by finger pressure on either side of the incision while the cut surface is being inspected. It must be remembered that the appearance is greatly altered by the consequent anæmia. The liver wound is dealt with as already described.

The **insertion of radium** should only be carried out through an open incision and with the part to be treated fully exposed. The containers are passed into the tumour in various directions, attention being especially paid to the periphery. The strings from the several tubes are then collected and brought out of the abdominal incision by the shortest route through the lumen of a piece of rubber drainage-tubing.

Operative treatment of pylephlebitis.—The acute variety is almost invariably fatal, and the mortality is not likely to be diminished by operation. On the other hand, the subacute and chronic varieties are not so fatal as was formerly thought, and it is very questionable if operation is likely to improve the recovery-rate. There is reason to hope that some of the newer sulphanilamide drugs, penicillin and other antibiotics may influence this condition. The first *essential* is the treatment of the focus, and in what follows it is assumed that this has already been done. Ligature of the portal vein must be expected to be fatal unless some previous communication has been established between the

* Blakemore-Whipple, loc. cit., also Learmonth and [illegible] ...48.
[illegible]

portal and systemic circulations. If operation is decided on, the liver should be exposed for inspection to make quite certain that there is no localized abscess that might be dealt with. The area should then be covered with gauze, which is left *in situ*, so as to encourage the formation of adhesions and to establish a direct track to the surface. The omentum should be fixed to the abdominal wall and to the edges of the parietal incision, as in the operation of omentopexy for ascites (q.v.). Three weeks later, if rigors still occur, the trunk of the portal vein may be tied as it lies in the edge of the gastro-hepatic omentum. In some few of these cases a localized abscess ultimately forms and has to be drained.

When the focus of infection is in connection with the appendix, it might be more rational and useful to excise the cæcum and lower part of the ileum together with the venous area involved, as in the Jamieson-Dobson operation for malignant disease of the cæcum.

Injuries to the Portal Vein

These may occur as the result of external trauma or during operations *on the bile-ducts, or a portion of the wall of the vein may be deliberately* excised during the removal of tumours. Unless prepared for and especially guarded against, the hæmorrhage will be alarming, dark venous blood welling up in large quantities. The first step is to control the hæmorrhage temporarily by immediately thrusting a finger or fingers into the foramen of Winslow and lifting the vein forwards. This alone may suffice to stay the hæmorrhage but, if not, the bleeding-point may be compressed between the finger and thumb. Another plan is to thrust a large artery forceps down to the neighbourhood of the bleeding-point, taking a grasp of all the structures in the vicinity. This may stop the hæmorrhage and in any event, it provides a means by which the involved area can be drawn nearer the surface, and furnishes a handle for fixation of the deeper structures. But this step is only for desperate cases and as a life-saving measure, because the bile ducts or the duodenum may be seriously crushed. Its object is to enable the surgeon to search for and discover the actual site of injury and as soon as that has been done *the blindly-applied forceps must be removed.*

The hæmorrhage having been temporarily arrested, the next step is to remove the escaped blood and clots and to secure proper exposure. *The exact site of the injury* must now be carefully sought and dealt with. A small tear may be caught in forceps and a lateral ligature applied, the ligature material should be fine silk or thread, as thin catgut cannot be drawn tightly enough to get a secure hold. If the tear cannot be ligatured long forceps can safely be left *in situ*, provided they only occlude the actual hole in the vein, i e. they must be disengaged from any other portion of the vein or other structure which they have in their grasp and reapplied to the torn area *only.* Forceps left on in this way should be loosened at the end of seventy-two hours and may be removed four hours later if there is no further bleeding. Long lateral tears or *deliberate incisions* may be successfully sutured

by a continuous stitch of very fine catgut passed with a thin round needle. If the vein is almost divided across, the remaining channel must be spared at all costs, as the merest trickle of blood reaching the liver is far safer than occlusion. When the vein is completely divided, it may be possible to repair it by end-to-end-suture, using fine catgut. The condition of the patient and the circumstances of the case must determine the course which the surgeon takes in the face of this calamity, but the patient must never be allowed to die from unarrested hæmorrhage.

Deep bleeding about the hilum of the liver is not always from the portal vein. Smaller vessels may be caught and tied, or forceps left on a vessel difficult to ligature, and oozing may be treated by absorbable gauze packing. Some of the most desperate-looking accidents of this kind have had a happy ending when the surgeon has tackled the problem courageously, while many patients who have been left to their fate might have been saved. Immediate blood transfusion will usually be necessary after the bleeding has been arrested.

Injuries to the Arteries

These accidents usually occur during the performance of cholecystectomy. Probably they are mostly due to abnormal position of the vessels. It has been shown that in about 46 per cent. of subjects some vessel, either the right hepatic or the cystic, or an accessory cystic artery, passes in front of the common duct or the common hepatic duct (Fig. 369, p. 874), and is therefore very liable to injury.* It is surprising what severe bleeding may come from a divided cystic artery. Ligature of either main branch of the hepatic artery is very serious and is usually followed by fatal necrosis of the liver. Contemplation of this accident only serves to emphasize the possible risks of removal of the gall-bladder, and is a further warning of the need for great care in performing this operation. However, in the presence of bleeding, the vessel must be caught, in spite of possible consequences, as the patient cannot be allowed to die of hæmorrhage. What has already been said in the previous section applies here, and it is most important that only the actual bleeding-point should be occluded. The lateral ligature is difficult to apply to an artery, and if this seems indicated because of the risk of occluding the hepatic, it will be safer to leave an artery forceps *in situ*, or to do so in addition to the ligature. When artery forceps are left on important vessels their handles should be tied together with strong silk, as they sometimes spring open without interference. Sometimes a silver clip, such as is used in cranial operations, may be applied to the bleeding point.

OPERATIONS ON THE GALL-BLADDER AND BILE-DUCTS

Surgical interference may be necessary to deal with infections, to relieve mechanical obstructions, to remove gall-stones not complicated

* E. R Flint, *Brit. Journ. Surg.*, April, 1923, x, 509.

by either of the foregoing, to deal with other complications or consequences of gall-stones and with new growths of the gall-bladder or ducts, or for the relief of certain diseases of the pancreas.

General indications for operative interference.—Infection may or may not be associated *with gall-stones, and may be either acute or chronic.* Acute infections, such as occur in some cases of typhoid or paratyphoid fever, may rapidly subside, and all urgency disappear, yet operation may be the *wisest course because so frequently the infection* becomes chronic and remains a focus for systemic absorption, or gall-stones subsequently develop, or the patient becomes a typhoid

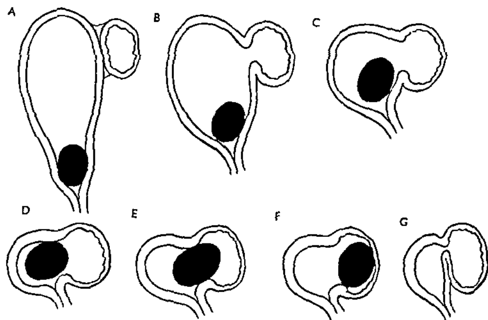


Fig. 380.—A series of diagrams showing how gall-stones may find their way into the hollow viscera. A, Calculus impacted in neck of inflamed and distended gall-bladder which has become adherent to the neighbouring bowel. B, Gall-bladder has ulcerated into the intestine. C, Gall-bladder drains freely into bowel, and tension *being released, it commences to contract. D, Contraction, which is partly due to the* development of scar tissue, continues and the calculus is pressed against the opening in the bowel. E and F show transit of calculus into the bowel. G, The calculus has travelled on down the intestine, the fistula contracts, and the gall-bladder continues to shrivel.

carrier. Either in the foregoing circumstances or when infection is a *complication of gall-stones,* the following are definite indications for operation: right-sided peritonitis spreading from the gall-bladder region; recurrent rigors with persistent tenderness over the gall-bladder; distension of the gall-bladder, with pyrexia; persistent tenderness over the gall-bladder quite apart from its enlargement or the degree of pyrexia. In other cases there may be symptoms and signs suggesting pancreatitis, and these may indicate operation

Mechanical obstructions are most commonly caused by the impaction of a calculus in the neck of the gall-bladder, the cystic duct, or the *common bile-duct.* In either case, the onset will probably be attended

by an attack of colic, and this may be followed, on the one hand, by a distended gall-bladder or, on the other hand, by jaundice. With a history of gall-stone attacks, the discovery of a distended viscus is a sufficient indication for operation, but it must be sought for just after the severity of the attack has subsided, which is the best time to make the diagnosis. It is true that such a distended gall-bladder frequently empties itself, either because the stone passes on or is released, or because the organ becomes adherent and leaks into one of the neighbouring viscera. This event allows the fluid contents and sometimes the calculi to escape, but more commonly the latter remain, though the presence of the communication with the bowel acts as a safety-valve and relieves all symptoms. In these circumstances, the gall-bladder may slowly contract on the stone and at some period remote from the attack cause it to erode into the intestine, where it may be the cause of obstruction of the bowel (Fig. 980). Jaundice due to gall-stones is a comparatively late complication, and one that would rarely occur if the earlier symptoms of gall-stone were more frequently recognized as indications for surgical treatment. Intermittent or steadily deepening jaundice are both indications for interference.

Operation in the absence of infection or mechanical obstruction.—The symptoms due to gall-stones can be relieved in various ways, but there is no known method of medical treatment which will cause them to be dissolved or voided with certainty, and the only means of cure is by operation. In some cases all the calculi safely traverse the ducts or pass through internal fistulæ into the gastro-intestinal tract, but there is no assured means (except perhaps occasionally the X-ray findings) of ascertaining whether or not this has taken place. No interval of freedom from symptoms is enough to signify that the stones are gone, for they may lie dormant only to give trouble again after many years. There is, further, the ever-present risk of the onset of some complication. Operation in simple cases carries a mortality of about 2 per cent., but in the presence of complications this rapidly mounts to about 10 per cent. In quite a number of cases cancer ultimately develops in gall-bladders which have for long harboured calculi.

It should be realized that whenever the biliary tract is diseased there is probably some disturbance of liver function, so that the choice of the best time to operate and the preparation of the patient are important matters

The best time to operate.—Before any operation on the gall-bladder or ducts, some preparatory treatment is a great advantage. There are, of course, certain cases of gall-bladder disease, such as phlegmonous cholecystitis and perforations, which must be operated upon as emergencies. It is not wise to operate during an attack of colic, nor is there any special reason for doing so, for there is very little risk of urgent complications, and pain can be relieved temporarily by other means. Symptoms and signs of infection may dictate the time for operation, but whenever possible it should only be done in an interval.

In the jaundiced case the surgeon should stay his hand in the hope that the jaundice may disappear or lessen, and in order that the very necessary measures for diminishing the tendency to hæmorrhage may be taken. If the condition of the patient is improving, it is safer to defer interference until bile is finding its way into the bowel. In deciding the very difficult question of how long it may be wise to wait for an attack to pass off, the history and progress of previous attacks may be a useful guide.

Preparation.—The necessity for the special preparation of patients about to undergo operations on the biliary tract has been recognized as important since the rôle of the liver in general well-being has been better appreciated, and still more since it has been realized that in nearly all conditions calling for surgical intervention both the liver and pancreatic functions are deranged in some degree. Unfortunately, there is no simple test for liver function which will give a reliable indication of those minor changes which may be so important.

No special preparatory treatment is necessary for patients who are not suffering from jaundice, ordinarily enjoy good health, respond satisfactorily to their environment and make quick and complete recoveries from their attacks of biliary disability. Though no special pre-operative treatment may be necessary, it is none the less unwise to take these patients straight " off the street ", so to speak, and carry out an important abdominal operation. Even the mildest cases are better for a couple of days spent in hospital and probably in bed. Where there is no urgency very stout people, or those who are merely bulky and indolent, can usually be got into a better condition for operation by a delay of two or three weeks, during which time they are ordered a reasonable dietetic regimen with avoidance of fats, moderation in the use of alcohol and tobacco, and regular walking exercise. The *hygiene of the mouth and the treatment of chronic* bronchial infections should also receive attention. In all patients admitted to hospital it is necessary to overlook the systems generally and especially to be assured that the excretory apparatus is doing its work efficiently. Quite often, those just recovering from gall-stone attacks are also suffering from the effects of morphia and the disabilities due to that drug should be overcome. Special preparation is imperative when liver or renal function appear poor, either because of the patient's tardy recovery after an attack of biliary illness or from the results of laboratory investigations. Even in the absence of jaundice, such patients tend to be lethargic, there is often much wasting, they are dehydrated and generally chilly, and should certainly be under treatment in hospital for at least a week before any interference. Confinement to bed is essential and this alone does much good, especially in warm, comfortable circumstances with a restful environment. The bowels should be really well moved, and the urinary output must be kept up to normal or increased, and for this purpose patients should be encouraged to take bland fluids in abundance—several pints in

24 hours. Nothing is better than water, though the patient may be encouraged to take it more readily if it is flavoured with lemon or disguised as weak tea. These patients should also take a high carbohydrate diet rich in vitamins. If they do not readily respond to this régime, glucose should be freely administered, either by the mouth or intravenously. A total of 3 to 6 oz. (100 to 200 g.) should be given daily in one form or another. Anæmia should be treated, and the patients should have blood transfusions when necessary. If there is gastric distension, or the patient is at all nauseated it is well to use a small stomach tube, not so much to draw off any residue as to accustom the patient to this treatment, as it may be invaluable during the immediate post-operative period. If there is any remaining elevation of temperature or if fever has played a part in the illness, then one of the sulpha group of drugs, probably sulphadimidine, will be administered as a biliary antiseptic. Any disabling condition associated with the heart or the lungs or with metabolism, such as diabetes, must be treated in order that the operation may be carried out under the best possible auspices.

In the presence of *jaundice* further preparation is required, as there is great risk of post-operative hæmorrhage or failure of liver function. These risks are belittled by some surgeons, while others have found that hæmorrhage has been the cause of death in about 16 per cent. of their cases. In all cases of established jaundice laboratory investigations are necessary and no patient should be subjected to operation without careful preparation. Some indication of the risk of hæmorrhage can be gathered from the ordinary clinical examination of the patient, for there may be petechiæ or spontaneous subcutaneous hæmorrhages, or even bleeding from any scratched surface. The laboratory evidence of increased bleeding time and coagulation time are also helpful while the estimation of the blood prothrombin is of the greatest value and indicates those jaundiced patients in whom hæmorrhage will probably occur. Certain measures to diminish this risk have already proved their value, and in consequence the mortality of operations in jaundiced patients has been much reduced during the last few years. Of the measures which have already been mentioned, the administration of fluids and glucose are especially important.

Since it is usually necessary to administer a considerable amount of the fluid required by the intravenous route it is essential to keep records of the intake and output so that a proper balance may be established, as there is a risk of water-logging of the tissues which may be indicated by subcutaneous or pulmonary œdema. It is also essential that intravenous administration should be at such a rate that the constituents can be assimilated. Two hours for each 200 c.c. is probably about the optimum speed. If the circulation is good it may sometimes be more convenient to administer extra fluid per rectum. In cases with well-developed jaundice 2,000 c.c of 5 per cent. glucose in normal saline should be administered intravenously in addition to what can be taken by mouth. Calcium is of proved value for directly influencing

the hæmorrhagic tendency. Parathormone (0·5–1 c.c. by the intramuscular or intravenous route) helps to maintain the calcium concentration in the blood, and some authorities advise that it should be administered daily until the risk of hæmorrhage is past (about ten days). When there is evidence of a well-established hæmorrhagic tendency preliminary blood transfusion should also be employed and may of course be most valuable post-operatively for its hæmostatic properties. Though there appears to be no laboratory proof of marked deficiency of Vitamin C in obstructive jaundice, orange juice or ascorbic acid in some form has appeared to be a material help in some cases.

I am fully convinced that these measures are valuable and have contributed to much improved results in my own cases. Certain additional measures, based on accumulating knowledge of the factors which activate prothrombin, have become current practice. Patients with obstructive jaundice who are liable to excessive bleeding have low prothrombin levels. The synthesis of prothrombin in the liver requires the presence of Vitamin K and the maintenance of normal blood prothrombin depends on the presence of adequate quantities of Vitamin K, which is absorbed from the intestine only in the presence of bile salts. In obstructive jaundice, where the bile salts are diminished or absent from the intestine, Vitamin K is imperfectly absorbed. The hypoprothrombinæmia may be corrected before operation by giving bile salts and Vitamin K by the mouth, or Vitamin K alone may be administered by intramuscular injection. Where the prothrombin value remains low, this treatment should be used for three or four days both before and after operation. But whatever steps are taken by way of preparation, they cannot excuse any lack of care in the selection of the time to operate, and the need for precision in carrying out the operation and after-treatment. Gentleness is essential, and every bleeding point that can be caught must be ligatured and the incision must be carefully sutured in order to diminish the risks of hæmorrhage into it.

The local preparation of the operation area is a matter for the predilection of the individual operator, and it is only necessary to offer a warning against over-preparation, which may defeat its object and be wearisome to the patient.

For *anæsthesia* chloroform must be avoided and the gas, oxygen, ether sequence will often be the method of choice. For patients who are jaundiced and in very bad condition spinal anæsthesia offers some advantage in that possible toxic effects are reduced to the minimum and the parenchymal liver cells are not harmed.

The operations which may be required are—

Cholecystostomy.—The gall-bladder is opened, its contents removed, and its interior drained on to the surface of the body.

Cholecystendysis.—After removal of its contents, the gall-bladder is completely closed by suture and returned to the

abdomen without drainage. (The use of this term, instead of cholecystotomy, avoids the confusion which is apt to arise when words so similar as cholecystotomy and cholecystostomy are employed.)

CHOLECYSTECTOMY.—The gall-bladder with its contents is completely removed.

CHOLEDOCHOTOMY.—Stones are removed from the common duct, with or without drainage.

Sometimes other procedures are required which do not involve any separate principle or special technique, and which are really only extensions of one or other of the above measures, and are therefore better unencumbered with special names. The operation of lithotripsy—crushing calculi *in situ*—is entirely different in principle from the others mentioned. It is scarcely ever used at the present day except as a means of dealing with the soft pigment calculi which may be found when splenectomy is performed in acholuric jaundice. Combined operations are sometimes necessary when stones are present in the great ducts as well as the gall-bladder. Although the clinical history, and to a lesser degree the physical signs, will give some indication of the type of operation likely to be called for, this can only be certainly decided after the abdomen is opened and the preliminary examination made.

Choice of operation.—The question whether or not the gall-bladder should be removed as a routine is still unsettled, and will remain so until it is possible to review in more detail the continued after-history of larger numbers of cases in which the alternative methods of dealing with the gall-bladder have been tried. This viscus must have some function, possibly it may regulate bile flow or it may only concentrate the bile or be responsible for the secretion of a hormone. In the environment in which mankind now exists it is evidently of no great importance, or its absence is very well compensated, as so many thousands of people are known to be in good health years after its removal. It was predicted that after removal of the gall-bladder the functions of the liver would be seriously interfered with as the result of the dilatation of its ducts and the unaccustomed pressure within them, and that in a few years there would be an outcrop of cases of hepatitis, the result of this operation. This has not proved to be the case.

The principal reasons advanced in favour of cholecystectomy are as follows :—

1. It removes the site in which gall-stones usually form.

2. It removes the focus in which infection is most likely to persist. For these reasons it is the best safeguard against both the recurrence of calculi and the persistence of infection.

3. It prevents many cases of biliary fistula, and eradicates more efficiently potential as well as actual pathological processes.

4. It eliminates the risk of subsequent cancer in the gall-bladder.

From a technical point of view it is also urged that the immediate convalescence is easier and shorter, because it does away with the necessity of prolonged bile drainage, and that for the same reason the abdominal scar is stronger. It is also said that cholecystectomy implies [illegible] ially carried [illegible] is an argu- [illegible] operations rather than a reason for cholecystectomy.

Against the operation it is urged that there is grave risk of injury to the deeper ducts, with possibly serious consequences, and that there is greater risk from hæmorrhage. There can be no doubt about these contentions, though not many disasters from hæmorrhage have been recorded. Injury to the ducts is unfortunately not rare and is the primary cause of many tragedies, but these accidents are largely due to the fact that the difficulties and dangers have not been properly understood. They are strong arguments for the proper selection of cases, and for greater care in performing the operation, but they need not deter the serious surgeon from carrying out cholecystectomy with increasing frequency, for the weight of evidence, as judged by the after results, is very much in its favour.

Though the proportion of recurrences of calculi is undoubtedly higher after simple drainage, it is equally true that many patients after removal of the gall-bladder suffer from vague abdominal discomforts which may be distressing. Both sides of the question appeal to the public and as a result of the experiences of their friends some patients insist that the gall-bladder should be removed while others are equally anxious that it should not be sacrificed.

Positive indications for the operation are · (1) A calculus in the cystic duct or neck of the gall-bladder so tightly impacted that it cannot be removed without risk of subsequent stricture or obliteration. (2) Stricture or obliteration of the cystic duct (3) Small shrivelled gall-bladder with much-thickened walls. (4) When there is any suspicion of early malignant disease of the viscus

Contra-indications are : (1) Some anomaly of the ducts which may much increase the risk of injury to the common duct (2) Jaundice. (3) Uncertainty in diagnosis. (4) Great inflammatory thickening obscuring the parts about the neck of the gall-bladder. (5) Great general vascularity, with the risk of severe bleeding from the liver bed which may be difficult to control (6) Excessive obesity which may increase the difficulties and risks of the operation to an unjustifiable extent.

Between these two groups of case there are many in which the decision will depend on the actual conditions, on the state of the patient, and on the experience of the individual operator. When in doubt, the surgeon should drain rather than remove the gall-bladder, and it must always be remembered that if necessary the viscus can be excised at a second operation, when the conditions for both patient and operator are perhaps more favourable

Choice of operation after the abdomen has been opened. (1) Cases without jaundice.—(a) *The gall-bladder is pathological but does not contain stones, and exploration shows that there is no other sufficient cause to explain the symptoms.*—In these cases it is most difficult to arrive at a proper decision. It is imperative to remember that in about 5 per cent. of cases stones are present in the main ducts though absent from the gall-bladder. External examination may show adhesions between the gall-bladder and omentum, colon or duodenum, which are very significant if limited to this region but of much less importance if also present in other parts of the abdomen. Thickening of the wall of the gall-bladder, whether from chronic inflammation or from recent œdema, and enlargement of the glands at its neck, are evidences of gross change originating in the viscus. An unusual amount of subserous fat is also looked upon as an evidence of infection. If there is doubt, it is much wiser to open the gall-bladder at the fundus in order to inspect its contents and the mucous membrane. Thick tenacious bile, bile of varying consistence, or bile with an obvious excess of mucus or with a decided odour, is pathological. Or there may be tiny calculi or bile-sand which can be readily seen, though not detected by palpation from without. When the mucous membrane is of the well-known " strawberry type ", or shows congestion in patches or papillomata, there is probably sufficient evidence of pathological change to justify excision. Inability to empty the gall-bladder by gentle squeezing suggests that there is some anomaly about the neck or the cystic duct which may explain the symptoms. In these circumstances anastomosis of Hartmann's pouch to the common duct has led to permanent relief (Pribram). It is in this class of case that immediate cholangiography may prove to be most useful. Cases without stones furnish many of the recurrences after simple drainage and, though the surgeon may hesitate to remove the gall-bladder for what appears to be very limited disease, it is probably often the best course. The decision must rest with the individual operator and be dictated by his interpretation of the conditions found in their relation to the clinical symptoms.

(b) *The gall-bladder contains a single calculus, or multiple calculi, but there is no sign of inflammatory trouble, and there are no stones in the ducts.*—In these circumstances the surgeon must be guided by his views on the pathology of gall-stone disease. Either operation gives good immediate results, but to remove the gall-bladder ensures their greater permanency. Unless some of the contra-indications are very definite, excision will probably be best.

(c) *The gall-bladder contains stones and is obviously much altered as the result of chronic infection, or is small, thick-walled, and glistening.*—Removal is certainly indicated, for these are the very cases in which early malignant disease may be present, but without any sign by which it can be recognized by the naked eye.

(d) *There are stones impacted in the neck of the gall-bladder or cystic duct, with great or moderate distension of the gall-bladder.*—If the distension is recent and due to bile, removal of the stones and drainage

will be attended by good results, and collateral circumstances must decide whether the gall-bladder is to be removed. Old-standing obstructions and hydrops are best treated by cholecystectomy.

(*e*) *The gall-bladder contains calculi and is big, thick-walled, and œdematous from active pyogenetic infection.*—Here drainage is undoubtedly the safer proceeding, for in these cases the parts about the neck are often difficult to expose, and there may be an alarming amount of hæmorrhage from the liver bed due to the recent inflammation. Of course, special care must be taken to see that the obstruction in the neck of the viscus has been removed. It must be remembered that the gall-bladder has remarkable recuperative power, and, further, that it is always possible to perform a cholecystectomy as a secondary operation when the inflammatory mischief has subsided.

(*f*) *The gall-bladder is gangrenous, or is the focus of a right-sided peritonitis, or is associated with an intraperitoneal abscess.*—In these cases only life-saving measures are justifiable. Drainage must be carried out in the first instance, and when there is evidence of infection outside the gall-bladder, drainage from these parts must also be provided. When the fundus of the viscus is gangrenous, it alone may be cut away, but even this step may be dispensed with in a patient who is very ill. The remarks made under (*e*) apply here, but no time should be wasted in vain attempts to remove a firmly impacted stone from the cystic duct. The risk to the patient is from infection, and if that is overcome the calculi can be dealt with later. Sometimes such a stone loosens during convalescence and is extruded through the drainage-tube.

(*g*) *There are many small stones in the gall-bladder, and the patient gives a history of repeated attacks of transient jaundice, but no stones are felt in the common duct.*—It is often impossible to palpate very small stones in the common duct, but with a history of only transient jaundice it probably means that they have passed safely into the duodenum in each attack. If the common duct is thickened or œdematous or if the contents, as determined by the exploring needle, are turbid, then the duct should be opened. If no stones are found, a thick probe or a Lister's bougie 7/10 to 9/12 should be passed down the duct into the duodenum. The gall-bladder must be dealt with either by drainage or removal. The surgeon must not be disappointed if the patient has an attack of colic during convalescence.

(*h*) *The gall-bladder is small, shrivelled, and adherent, and there is a history of jaundice, but no stones are found.*—In these cases the stone has probably passed in the last attack. It is best to remove the gall-bladder and establish external biliary drainage from the common duct a large probe or a Lister bougie being first passed into the duodenum to ensure the patency of the duct.

(2) Cases with established jaundice.—(*a*) *A calculus is plainly felt in the common duct, and the gall-bladder also contains stones.*—To expose the common duct it may be necessary to divide many adhesions and to separate the colon or duodenum from the gall-bladder. In any event, the stone in the duct should first be dealt with, though on rare occasions

it may be necessary to empty the gall-bladder first to facilitate exposure of the duct. The supraduodenal part of the duct should be opened first, even though it may later be necessary to deal with the stone by some other route. The stone in the common duct having been removed, the gall-bladder should be emptied. It is a sound general rule not to remove the gall-bladder if there has been an impacted calculus in the common duct.

(*b*) *No stone is felt in the common duct, but there are multiple small stones in the gall-bladder, and there have been previous attacks of jaundice.*—The duct must be opened and explored, and if no stone is found the large common-duct probe or a bougie must be passed into the duodenum.

(*c*) *The gall-bladder is small and shrivelled, and the common duct is so covered with adhesions and so thick from surrounding inflammatory thickening that it cannot be identified.*—An incision should be made in the position of the common duct. If calculi can be found and removed, well and good, but if not, the surgeon should be content to establish external bile drainage and to operate at a second sitting, if necessary. It is in cases of this class that a stone is frequently found to have passed while the inflammatory thickening remained. The common duct may often be identified by introducing a fine exploring needle obliquely upwards into its supposed site. The withdrawal of bile confirms the position of the duct.

(*d*) *The gall-bladder and ducts are nodular and hard.*—The condition is almost certainly the result of new growth. Nodules in the liver or outlying nodules on the peritoneum are valuable confirmatory signs. In these circumstances intervention is of no avail and it is unwise to open the gall-bladder even if it contains stones. When possible an outlying nodule should be removed for microscopic section and the abdomen should be closed without drainage.

(*e*) *The gall-bladder is greatly distended with bile, but no stones are present.*—The lesion is probably in the head of the pancreas and may be inflammatory or neoplastic. If an examination can readily be carried out without separating adhesions and thereby running the risk of producing bleeding, a diagnosis of the cause of the obstruction may be made. Otherwise the experience of the surgeon must decide whether to be content to make a permanent anastomosis between the gall-bladder and the gastro-intestinal tract, or to establish external bile drainage with a view to a secondary operation.*

General technique. Number of assistants.—This is entirely a matter of practice. For most operations experienced surgeons will require only one assistant, and more will be an encumbrance. For difficult common-duct cases, or in big, fat subjects, an additional pair of hands to make traction on the liver or to keep the viscera aside may be very helpful.

* *See* Chapter XVII on the Pancreas, p. 980.

Instruments. (Fig. 381.)—These, again, are a matter of choice; the fewer special instruments that are used the better. Though it is not generally recommended in upper abdominal incisions, I have found the Balfour self-retaining retractor very satisfactory; the Devine retractor is equally useful but slightly more complicated. A simple retractor with a long blade made of malleable copper, 4 in. by 1 in., is also very useful for cases in which the liver does not lend itself to the

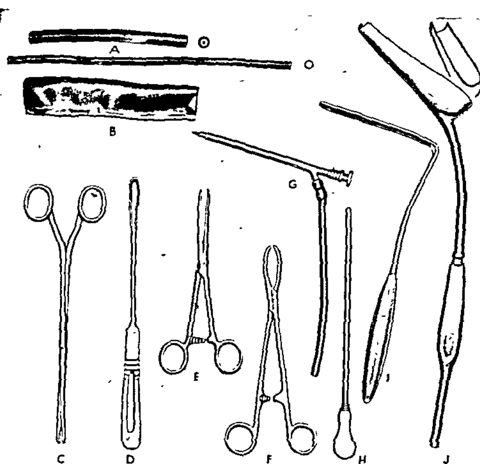


Fig. 381.—Instruments used for operations on the liver and biliary apparatus

A, Drainage-tube with specially thick wa[illegible] C, Desjardins' forceps for the common duct, D, gall-stone scoop, [illegible] bner trocar, H, female bladder-sound used as probe for [illegible] J, receiver

method of displacement, or when it is necessary to expose the parts about the hilum. Small volsella-pointed forceps, known in Newcastle-upon-Tyne as "catch forceps", are extremely handy for holding the cut edge of the gall-bladder or the common duct. For cholecystectomy some type of long artery forceps (7 in.), with a slightly curved grasping surface, is essential. The gall-stone scoop of Lawson Tait is the best pattern, though it is well to have a smaller size available for exploring the ducts and this should have a malleable handle. For extracting stones from the lower end of the common duct the well-known Desjardins' pattern forceps is the best. (Fig. 402) Any type of trocar and

cannula to empty the gall-bladder will serve the purpose, but it should have an internal diameter of $\frac{3}{16}$ in. in order that thick mucus and tenacious bile may traverse its lumen with ease. Some form of receptacle is necessary into which the contents of the gall-bladder can be emptied; a small enamelled tea-cup which can be boiled with the instruments serves this purpose, or the instrument illustrated (Fig. 381, J) may be used, and is convenient and cleanly. It consists of a boat-

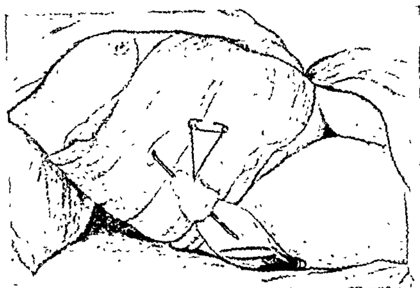


Fig. 382.—Bile-drainage into baby's feeding-bottle suspended from dressings.

shaped container mounted on a long hollow stem with a handle. The edge of the container is held against the gall-bladder, and the contents of the latter are emptied into it. Fluid, with débris and small stones, is conducted away through the hollow handle while the bigger stones remain in the boat and can thus be removed without soiling the field. A probe made of lead, and similar to a female bladder-sound, with a diameter of $\frac{3}{16}$ in. is convenient for passing down the common duct to demonstrate that its orifice into the bowel is free. A Lister's bougie, size $\frac{7}{10}$ or $\frac{8}{11}$ is also useful for this purpose. Needles for suture of the liver must be half-curved and of the intestinal pattern, and with an eye

bes.

irm

an

encircling fixation suture. The gall-bladder tube should be $\frac{1}{2}$ in. in outside diameter (little-finger size), and that for the common duct $\frac{1}{4}$ in. in outside diameter (half little-finger size, No. 10 rubber catheter). Tubes not intended to go inside the gall-bladder or ducts may be of the same size, but thin-walled and soft. Strands of folded rubber sheeting (made of thick dental rubber folded to be 1 in. broad and stitched along one edge) are very convenient when it is only necessary to provide a track to the surface, or to cover up a raw area on the liver, or to prevent the viscera from becoming adherent to gauze. A baby's

feeding-bottle suspended from the bandages is a convenient receptacle when external bile drainage is necessary. (Fig. 382)

Methods of exposure.—In most cases some type of *vertical incision* will fulfil the requirements. A paramedian incision ½ in. to the right of the middle line, with displacement of the rectus outwards, or a direct incision through the centre of the muscle, is very satisfactory. To get the full benefit of any type of vertical incision, it is essential that it should extend upwards to the costal margin, for it is

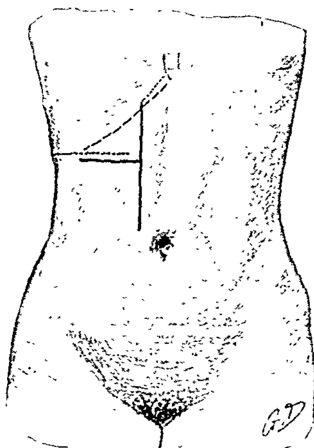


Fig. 383.—Incisions for exposure of liver or bile-ducts.

The vertical i
the exposure
of the bile-du

this upper part which allows proper rotation of the liver. In an ordinary case, any type of vertical incision should extend from the costal margin to an inch above the umbilicus. (Fig. 383.) Mayo Robson secured more room by extending the incision upwards and inwards to *the ensiform cartilage*, and Bevan made a similar extension outwards through the rectus, at *the lower end of the wound*. The *oblique incision of Kocher*, a finger's breadth below the costal margin, also gives an excellent exposure ; it extends from the ensiform right through *the rectus muscle*, and it may be carried back to the loin, or

may involve any part of this line, depending upon the indications. In 1930 Professor Pribram described an incision which takes the same direction as that of Kocher but commences over, instead of below, the costal margin. The rectus is divided and then retracted below the ribs, where the transversalis is divided in the same oblique line. The incision allows a good exposure and provides considerable insurance against hernia. A strictly *transverse incision* as described by Rutherford Morison* (Figs. 383, 384) is useful in the presence of suppuration. In stout subjects it is a good plan to mark out the proposed incision before the patient comes to the table, i.e. when the parts can be freely palpated and the landmarks defined. In any case, the incision in the skin and fat is to be 1½ in. or, in fat subjects, even 2 or 3 in., longer than that in the muscles. (Fig. 385)

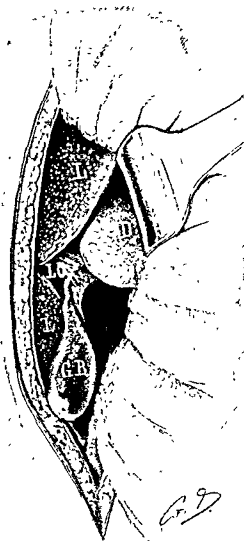


Fig. 384.—Parts, as exposed in transverse incision of Rutherford Morison.

L, Liver; LO, edge of lesser omentum; D, duodenum; GB, gall-bladder.

With any of these incisions great *additional help in exposure* can be secured by utilizing the normal mobility of the liver. The reversed Trendelenburg position encourages the liver to descend toward the incision and facilitates its rotation. The latter is brought about by traction on the gall-bladder, perhaps assisted by the hand passed behind the posterior border of the right lobe. The deeper ducts can also be brought much nearer the surface by elevation of the loin (Mayo Robson). This is secured by a bridge on the table operated mechanically, by an inflatable cushion, by a sandbag, or, very simply, by the use of the wooden wedges illustrated in Fig. 386.† The elevation should not be too high or kept up for longer than necessary as it may cause considerable post-operative backache. As soon as the peritoneum has been sutured the patient should be allowed to lie flat. When the oblique or the transverse incision is employed, further exposure is

* *Brit. Med. Journ.*, Nov. 3, 1894, ii, 1312.

† Grey Turner, *Lancet*, 1926, ii, 224.

secured by "opening out" the ilio-costal space by pushing the upper part of the trunk and the legs away from the incision, i.e. making the latter the apex of a wedge. Too much traction on the liver, passing the hand over the liver, or gauze packing introduced between that organ and the diaphragm should be studiously avoided. These methods tend to interfere with the free movement of the diaphragm and encourage post-operative pulmonary complications.

In any of these incisions, and especially the vertical ones through the rectus, it is important to spare all motor nerves. The latter should never be deliberately divided, but should be drawn aside, and even

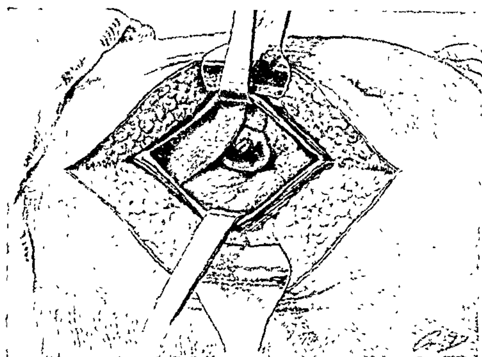


Fig. 385.—Exposure of gall-bladder in stout subject through vertical rectus incision. (*After Lilienthal, modified.*)

after a difficult and perhaps tedious operation they are often found intact when the incision is to be closed.

The *choice of incision* is most important, and is decided partly by the build of the patient and partly by the pathological conditions For all gall-bladder and common-duct conditions without suppuration, and in spare subjects, the paramedian or the vertical rectus incision gives sufficient room. In the obese the oblique incision of Kocher often gives a better exposure, but it may have to be prolonged back towards the loin For cases of suppurating gall-bladder, or those in which an inflammatory mass is felt, the transverse incision of Rutherford Morison is very suitable, and is admirable for drainage When the diagnosis is in doubt and it may be necessary to examine the appendix or the duodenum and stomach, one of the vertical incisions should be selected.

The *suture* of these incisions is most important for the prevention of

hernia. The peritoneum and transversalis should be brought together by a *continuous* catgut stitch, and the outer muscles by two layers of interrupted sutures, No. 1 or 2 chromic gut being employed, according to the bulk of muscle and the tension. In all cases a through-and-through silkworm or wire stitch should be introduced every 3 in. Care

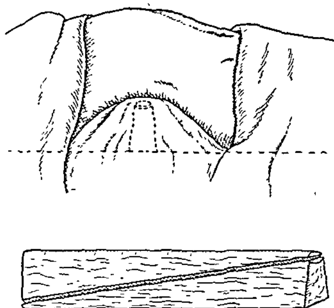


Fig. 386.—Elevation of loin (Mayo Robson position) by use of wooden wedges passed from either side after patient is on table.

must be taken to remove the lumbar support, and to appose the edges of the wound as far as possible before completing the suture.

The general examination on opening the abdomen.—The first step is to confirm the diagnosis of gall-bladder mischief. The surgeon should next, as a routine, examine the common and hepatic ducts. Though calculi in the ducts can usually be detected by external palpation there are some which evade the best-trained fingers. The surgeon must therefore be prepared to open the common duct in the absence of palpable calculi in the following circumstances: when (*a*) there is a history of recurrent attacks with jaundice; (*b*) the duct is found to be distended, thickened, œdematous or unduly vascular; (*c*) the lymphatic glands in the vicinity are enlarged; (*d*) exploration with a hypodermic needle shows that the contents are obviously infected, or turbid, or contain bile sand or are white and limpid. In jaundiced cases, when stones are felt in the ducts, no further examination should be made, as there is always some risk of causing hæmorrhage by even the gentlest manipulations. Similarly, in malignant cases only such examination as is necessary to determine the extent of the disease is justifiable. In other cases the pyloric region, the duodenum, and the head of the pancreas are examined in order. The appendix should next be seen and, unless very adherent, can usually be brought into view by any of the methods of approach which have been described

and without any extension of the incision. This examination of the appendix is especially important when the gall-bladder does not show a degree of pathological mischief consistent with the clinical symptoms. The gall-bladder must only be dealt with in response to the conditions found, and not simply because a pre-operative diagnosis of gall-stones has been made.

The next step is to determine what type of interference with the gall-bladder and ducts is necessary. This may involve preliminary isolation

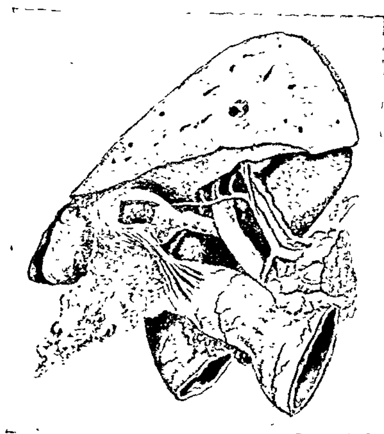


Fig. 387.—Showing adhesion of infundibuliform type between duodenum and gall-bladder. Such adhesions often contain a prolongation from the lumen of the bowel.
(After H L. Barnard, "Contributions to Abdominal Surgery")

of the gall-bladder by separation of adhesions, etc. ; this must be done with great care, and may be greatly facilitated by the method of gauze stripping. If the adhesions are vascular they should be caught in artery forceps before division, as even small vessels, when they retract, cause some subserous bleeding which may obscure the field. When the adhesions are to the hollow viscera there is great risk either of opening up some pre-existing communication with the latter—internal biliary fistula—or of opening into a long-drawn-out portion of the gastro-intestinal tract in an adhesion of the infundibuliform type. (Fig. 387.) It is not always easy to determine the contents and condition of the interior of the gall-bladder by external examination,

and this viscus may have to be opened for diagnostic reasons. For this purpose an incision about an inch long should be made in the fundus. Enlarged lymphatic glands, when examined by palpation, may so closely simulate calculi that they may have to be exposed before the decision can be made. For suture of the gall-bladder or ducts, the material should be fine chromic catgut (size 3/0) and the stitches should not perforate the mucous membrane, for even catgut sutures have been known to form the nuclei of recurrent calculi. (Fig. 388.)



Fig. 388.—Suture of chromicized catgut forming nucleus of gall-stone in a recurrent case. Actual size.

(From specimen kindly lent by the late Hamilton Drummond.)

Drainage.—It is always wise to bring a tube from the neighbourhood of a ligatured or sutured duct, as there is sometimes bile leakage which cannot be explained. Such tubes should be fixed to the skin rather than to the wall of the duct, as in this way the surgeon has absolute control of their removal. During the completion of the operation the drains are very apt to slip out of the gall-bladder or ducts, and they should be threaded on the long end of a ligature (Fig. 395, p. 937) or lightly fixed to the cut margin of the duct with a catch forceps (Fig. 381, F) until the closure of the incision is completed. The final removal of the drainage-tubes depends upon the circumstances of each individual case, but ten days is an average time. If drainage for a longer period is necessary the discharge of bile will continue in spite of the fact that the tube is gone. As a rule the flow of bile ceases two or three days after removal of the tube, but if there is coincident pain or rise of temperature there is probably some unrelieved obstruction or inflammatory trouble. Small tubes, which are merely left as a safeguard, need not be removed until the wound is first dressed. Almost the only indication for the use of gauze packing is oozing which cannot be otherwise controlled,* but it may have to be employed to soak up an excess of bile escaping by the side of a drainage-tube in the common duct, or to shut off some infected area. Its use should be avoided whenever possible, and it should never be packed against sutured ducts or bowel, as the union is very apt to be torn when it is removed. Iodoform gauze is not well tolerated by the liver, and should not be introduced. The hollow viscera should always be protected from contact with gauze by rubber tissue. Raw areas on the liver should also be protected, to prevent the viscera, and especially the stomach, becoming adherent, with possible subsequent kinking and obstruction.

General after-treatment.—The patient should be so placed in bed that the operation area is relaxed. At first the legs must be kept

* The use of absorbable gauze is proving a great help in the management of oozing areas.

flexed over a pillow, but after a few hours the patient may be propped up in a half-sitting position. If there is much pain it is better to give a small dose of morphia (gr. ¼) on the night of the operation but after that the surgeon should not hastily give morphia, but should look for and treat the cause of the pain. If the patient is shocked, and in all cases of jaundice, plain tap water, and if necessary a little stimulant, may be given per rectum, either continuously or intermittently, whichever is the more comfortable. If the patient does not respond, the intravenous route should be employed at once, saline with glucose or blood being used. As soon as water can be taken by the mouth without discomfort it may be allowed. On the day following the operation the patient is often in considerable distress, complaining of tightness across the abdomen and shortness of breath, and the pulse may be much quickened. These symptoms are usually at once relieved by loosening the bandage. If they persist or recur, or are associated with the eructation of mouthfuls of fluid, it is an indication for the use of the stomach-tube, which often gives immense relief. In these circumstances a Ryle's tube may be passed and left *in situ* for twenty-four hours, or longer. At the end of twenty-four hours steps should be taken to assist the passage of flatus by a glycerine enema or the passage of a flatus tube. If vomiting persists after the first day or two, it may be due to the irritation of gauze or of tubes about the neck of the gall-bladder, and these should be loosened as soon as they have served their purpose. *Persistent emesis suggests pancreatitis.* Generally speaking, drainage cases do best when the escape of bile is early and abundant, but the loss of large quantities may have a deleterious effect, as shown by thirst, dryness of the mouth and throat and, later, wasting and signs of hepatic insufficiency. The loss should therefore be made up by abundance of fluid by the mouth or, if necessary, per rectum or intravenously. In these cases the tube will have to be removed early to encourage the entrance of bile into the bowel. In some few critical cases there may have to be bile-feeding, which is carried out by collecting the bile and feeding it into the stomach through a Ryle's tube twice in the twenty-four hours. Diluted bile may be administered per rectum, but it is questionable whether it is absorbed.

Complications.—These are unusual at the present day, with the more careful selection of the proper time at which to operate, the preparation of the patient, and the improved technique. *Hepatic insufficiency* is the greatest risk. The patient becomes progressively more drowsy, has no desire for nourishment, becomes limp and lapses into unconsciousness. For any patient who is not doing well the most valuable remedy seems to be the intravenous administration of 5 per cent. glucose-saline; a daily total of about 2,000 c.c. will probably produce the maximum result. The urinary output must be carefully watched and the onset of œdema noted. When the response is not satisfactory, transfusion with fresh blood should

always be tried. Nor should the importance of the old method of purgation be overlooked. *Hæmorrhage* may very rarely result from the slipping of a ligature. This type of bleeding is only likely to occur in the few hours immediately succeeding the interference. Such a catastrophe demands the instant re-opening of the abdomen. A late type of bleeding in jaundiced patients is much more likely to occur either some forty-eight hours after operation, or about the tenth day; it is usually a progressive oozing into the peritoneal cavity or into the wound, more rarely into the bile-ducts and bowel. A large amount of blood may accumulate in any of these situations. When there is no external bleeding it is essential to employ measures which restore the coagulability of the blood and make up for the amount lost while at the same time toxemia is counteracted. To restore coagulability vitamin K therapy seems to offer the most promise. To make up the volume, blood or plasma transfusion is best, but glucose-saline may be used as a substitute until blood can be obtained. Even if bleeding is not of any great amount, it is none the less a danger signal and should be met by prompt measures. If the hæmorrhage is into the wound, some of the skin-sutures should be removed, and the site of the oozing may then be packed with gelfoam soaked in thrombin or plain sterile gauze soaked in horse-serum or, if this fails, in snake venom (Russell's viper solution of 1 in 10,000) or turpentine, while the other measures mentioned are also employed.

Escape of bile into the peritoneum.—Fatal peritonitis has followed leakage from the divided cystic duct, but this should always be forestalled by bringing a small tube from the region of the ligatured duct to the surface. Sometimes bile escapes from the common duct and finds its way into the lesser sac, which it distends. A low grade of localized peritonitis follows, and the patient may become gravely ill.* This may be suspected when, in a common-duct case, the general condition is not satisfactory, there is sickness, the pulse rises, and there is an icteric tinge, with an epigastric swelling at the end of about a week. When the wound is re-opened and drainage of the lesser sac established, these cases usually do well.

Impaction of fæces is a frequent complication in jaundiced cases.

It is not at all uncommon for an isolated attack of severe colic to supervene two to four weeks even after most successful operations. This may be due to a small fragment of stone, a mass of inspissated bile, or a bloodclot traversing the ducts.

It should be realized that jaundice, if well established, is slow to disappear even in cases that are making good progress.

CHOLECYSTOSTOMY

Technique.—The choice of incision has been discussed. The steps of the operation are:

1. General exploration.
2. Isolation of the gall-bladder and protection of peritoneum.

* D. M. Douglas and G. Grey Turner, *Brit. Med. Journ.*, Aug., 1940, ii, 280.

3. Evacuation of the contents and re-examination of ducts.
4. Introduction of tube.
5. Toilet and closure of abdominal incision.

On opening the abd [illegible] out the general examination. When [illegible] tended or very tense, it may not be [illegible] ily by palpation or to reach the parts about its neck. In these circumstances it should be packed off and aspirated, as a first step. If there are stones in the cystic duct, the surgeon must at this stage assure himself that they can easily be manipulated back into the gall-bladder, or the case is one for removal of the viscus.

The next step is the isolation of the gall-bladder by gauze. Four swabs are arranged around the fundus, or the latter is passed through a hole in the centre of a large pack in such a way that the margins of the opening fit closely around the gall-bladder. For this purpose the mackintosh swab of Moynihan is very useful. This is the proper stage at which to open the gall-bladder, if it has not been previously necessary. It is most cleanly done by first using a *trocar and cannula*, which is thrust into the fundus and draws off the fluid contents; the puncture so made is then enlarged with the scissors to about an inch *in length. Any small vessels which spout ought to be caught and tied.*

The contents of the gall-bladder are removed with a gall-stone scoop, followed by the light introduction of a strip of gauze, which *serves the double purpose of entangling small stones and of absorbing* fluid and preventing soiling by the further escape of contents during the next step. The surgeon then passes his finger and thumb down *the outside of the neck of the gall-bladder until his finger-tip is in the* foramen of Winslow. In this way he reaches the lowest part of the cystic duct and works the fingers gently towards the gall-bladder, into which any stones or débris are "milked" back. At this stage there may be considerable difficulty in dislodging a stone which is firmly impacted in the neck of the gall-bladder or the first compartment of the cystic duct. This must be released by pressure with the finger and thumb. If necessary the force used may be considerable, but great care must be taken to apply it just over the lower end of the stone, and to ensure that the neck of the gall-bladder is not torn away from its attachments—an accident which would demand its removal. This difficulty in dislodging the stone may be met by incising the neck of the gall-bladder with a knife from within; or it may require a direct incision from the outside in the long axis of the duct (*cysticotomy*); or, if small, the stone may only be reached by slitting the gall-bladder and duct right down to the site of impaction. There may, further, be a little doubt whether a nodule felt is a stone or a gland, and on this point the surgeon must be satisfied before finally deciding to drain the gall-bladder. When he is assured that the cystic duct is free, the gauze in the gall-bladder is removed and the scoop again gently used. Finally, the finger should always be introduced into the viscus to make sure

that it is empty, and, if there is any doubt, this examination is combined with a further simultaneous examination of the parts about the neck by the fingers of the other hand working from outside.

The tube is now introduced; it should pass about as far as the middle of the viscus. The fundus is closed round it by a purse-string suture of No. 1 catgut, which takes a good hold of the wall of the gall-bladder but does not perforate the mucous membrane. If this tucks in the wall satisfactorily, one suture will suffice, but, should it not do so, a second may be used, or a couple of interrupted sutures passed at either side of the tube. When the gall-bladder is very rigid or thickened from œdema it may be impossible to invert it, and in these circumstances the opening may be drawn together round the tube by one or two interrupted sutures at either side. If the closure round the tube is not accurate the surgeon must use his discretion whether it is necessary to protect the area with gauze or with a strand of rubber tissue which will conduct any leakage to the surface. Unless there has been some soiling of the hepatic pouch (Morison's pouch), or some question about the integrity of the neck of the gall-bladder, no further drain is necessary. In either of the latter events, a soft rubber strand had better be brought from the depths of the pouch up by the side of the gall-bladder tube. It is best not to attach the fundus of the gall-bladder to the parietal peritoneum. Even if there is a considerable distance between the incision and the gall-bladder, the drainage-tube will safely bridge the gap and the surgeon need have no anxiety on this head, provided always that the tube is not removed sooner than a week after operation. The drainage-tube is brought out by the most direct route—usually through the centre of any vertical incision or the posterior end of the transverse or oblique variety. So called stab incisions (a horrid designation!) should be avoided. Drainage-tubes should be attached to the skin by a silkworm stitch and conducted through the dressings to the bottle for drainage. (Fig. 882, p. 919.) If prolonged drainage is necessary, it is best to attach the fundus of the gall-bladder to the peritoneum and transversalis fascia, and in about fourteen days to substitute a



Fig. 389.—Hour-glass gall-bladder of hidden type with fundus tightly contracted on single stone.

self-retaining catheter for the tube. When the gall-bladder is of the buried type (Fig. 389) or is very deeply situated, as in fat subjects, it may be well-nigh impossible to introduce sutures. In these circumstances they may safely be omitted if a strand of gauze is packed into the interior of the gall-bladder round the tube and is brought out by its side. Although this plan appears to be rather slovenly, it has never given the writer cause for anxiety or subsequent dissatisfaction.

After-treatment.—The only special point concerns the removal of the tube. It should not be taken out sooner than a week, and may be left as much longer as is considered necessary, having regard to the purpose of the interference. For instance, if the gall-bladder is obviously much infected, or if there is longstanding infection of the deeper ducts, or the patient is a typhoid carrier, drainage for several weeks may be required, and should only be terminated after bacteriological examination of the bile. After removal of the tube, bile may be discharged externally for a few days, but if there is no obstruction in the deeper ducts this may be expected to cease spontaneously in seven to twenty-one days from the date of the operation. If there has been much swelling about the neck of the gall-bladder, as in some of the acute cases, *the bile may not flow for three or four days after operation*, but in the majority it does discharge externally almost at once. Failure to do so suggests that either the drainage-tube or the cystic duct is blocked.

Cholecystostomy combined with Excision of the Fundus of the Gall-bladder

This may be necessary in cases of gangrene, or where the gall-bladder is unusually friable, or of hour-glass form with too narrow an isthmus to permit safe drainage. (Fig. 389.) The fundus must first be separated from the liver to the extent of the proposed removal. Some small vessels may have to be caught and tied, or under-run with catgut on a curved needle, and if necessary the bed from which the fundus has been separated may be closed by a couple of sutures. Any calculi in the gall-bladder are manipulated into the part to be removed, which may then be cut away with scissors without previous clamping, but vessels that spout must be caught and tied. The wall of the gall-bladder is now grasped by catch forceps and its remaining contents carefully dealt with, as already described. The new fundus may then be closed with a purse-string round a tube, or may be diminished by suture up to the point at which the tube emerges. If the closure is not very satisfactory, a soft rubber tissue-drain is laid over the suture-line and brought out through the parietal incision via the gall-bladder bed.

Cholecystendysis (Removal of Stones and Immediate Closure of the Gall-Bladder)

At one time this was looked upon as the ideal operation for gall-stones, and was advocated by Kocher.* Now that it is recognized

* Text-book of *Operative Surgery*, 1911

that gall-stones which give rise to symptoms are always associated with changes in the wall of the viscus, this method has been superseded by drainage or cholecystectomy. The writer sometimes employs it, however, in cases in which gall-stones are discovered in the course of some other operation, and there is no evidence that they have produced changes in the walls, i.e. for the incidental removal of gall-stones.

Technique.—If this step is only an extension of some other operation, the incision must be so enlarged that the fundus of the gall-bladder can be made easily accessible. It is isolated by gauze and opened. All bleeding-points in the incision are caught and tied with very fine catgut. The contents are removed, special care being taken to determine that the neck and cystic duct are free from calculi. The interior is now dried with gauze and the incision in the fundus closed. For this purpose catgut is used, but the sutures must not perforate the mucous membrane. The first stitch is to secure accurate closure and hæmostasis, for there must be no bleeding into the cavity. The second suture should be a purse-string in the peritoneum at least $\frac{3}{8}$ in. from the first, thus turning in a good area at the fundus. If the surgeon has the slightest doubt about the patency of the cystic duct or the accuracy of the closure, a small tube should be anchored to the fundus and brought through the parietal wound. It need not be removed till the first dressing, for it does no harm, and may at least add to the surgeon's peace of mind.

Cholecystocholedochostomy

When it is considered particularly desirable to retain the gall-bladder but there is doubt about its emptying capacity, an anastomosis may be made between its neck (infundibulum or Hartmann's pouch) and the common duct (Pribram*). The actual union should aim at an opening about an inch in length to allow for the contraction which invariably occurs, and should be made by direct suture with interrupted stitches. During healing external drainage from the vicinity should be provided.

Cholecystectomy

Technique.—The steps of this operation are as follows :—

1. General exploration.
2. Isolation of the gall-bladder.
3. Exposure and examination of the common, cystic, and hepatic ducts.
4. Isolation and division of the cystic duct.
5. Isolation and ligature of the cystic artery.
6. Separation of the gall-bladder from the liver.
7. Double ligature of the cystic duct.
8. Treatment of the liver-bed.
9. Drainage and toilet.

* Pribram, *Journal of Amer Med Assocn.*, April 22, 1950, cxlii, 1262–7

The parietal incision must be adequate, as every step has to be carried out under the guidance of the eye, and it is in this operation that the additional aids to exposure are so necessary and helpful.

The first step is to make the thorough examination detailed on p. 923.

There are two principal methods of removing the gall-bladder. One commences the separation at the fundus, the other deals first with the cystic duct and artery; the latter is much the better plan. The objection to beginning at the fundus is the difficulty of preventing blood running down and obscuring the more important region of the



Fig. 390.—Gall-bladder, with portion of common duct (shown with glass rod introduced) inadvertently removed during cholecystectomy.

neck, and the undoubted risk that, unless special care is taken, the hepatic and common ducts may be pulled up in the form of a loop and divided without being recognized. (*See* Fig. 396, p. 938.) There is also the further consideration that if some anomaly of the ducts contra-indicating excision is discovered when the neck is reached, it may be too late to retire gracefully.

peels off from its bed even on

able to remove such a viscus

its contents have been dealt with; or the method of partial excision may be utilized. For the former purpose one or two sutures are passed between such part of the gall-bladder as it is necessary to

retain and the peritoneal fringe skirting the gall-bladder fossa. One of the advantages claimed for the operation of cholecystectomy is that the gall-bladder with its contents can be removed unopened, thus avoiding any risk from contamination of the field. At the same time, it must be realized that though this is an ideal plan, it is not essential, and the surgeon need have no hesitation in opening the viscus if it is going to help the removal and make it safer so far as the ducts are concerned. Sometimes the gall-bladder is so much distended that it obscures the field, and the neck cannot be properly exposed

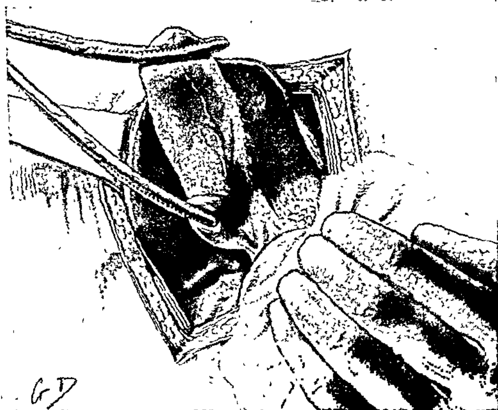


Fig. 391.—Cholecystectomy : first stage.

The fundus is grasped with forceps to be used as a tractor, and the infundibulum is drawn aside, exposing the hepatico-colic fold and the parts about the neck.

until the viscus has been diminished in size by aspiration. In these circumstances the fluid contents may be withdrawn by a trocar, which is then removed, and gauze clamped over the opening, the clamp acting as an efficient handle during the necessary manipulations. There is always risk of injury to the hepatic or the common duct in the operation. (Fig. 390.) The only way to avoid this calamity is clearly to see the three ducts before the cystic duct is divided. It may help in identification of the parts to distend the cellular tissue by the injection of a weak local anæsthetic solution (Riddoch*). The needle is introduced just beneath the peritoneal inflection from the

* J. W. Riddoch, *Lancet*, Jan 14, 1945.

gall-bladder and about 60 minims or more of solution balloons up the cellular tissue about the neck and much aids the dissection.

Removal by the method of choice.—*The first step is to expose the infundibulum.* This part is commonly obscured by adherent *omentum, which must be separated*, or it is adherent to the duodenum, which must be gently drawn away. This as a rule is easily done by *blunt gauze stripping*, but firmer adhesions may require the use of the scissors. The next step is to grasp the infundibulum with a strong

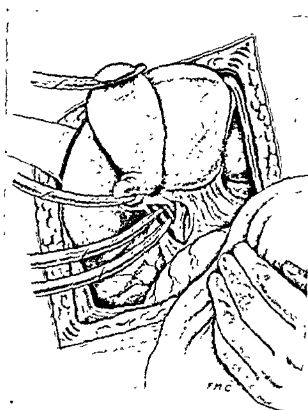


Fig. 392.—Cholecystectomy : second stage.

The three ducts are clearly exposed and the cystic duct has been isolated and caught in forceps ready to be divided between them

pair of curved forceps and to draw it gently towards the surface. (Fig. 391.) *This helps to expose the cystic duct and to straighten it.* It is next necessary to snip through the peritoneal sheath—the *hepatico-colic fold—which surrounds the cystic duct and artery* and commonly encloses a considerable quantity of fat. As soon as the peritoneum has been divided the scissors must be discarded and the exposure of the ducts completed by blunt dissection with the forceps, aided by *gauze stripping*. At this stage it may be found that the hepatic and the common duct are rotated in such a way as to lie over the junction with the *cystic duct, to which they are adherent*, but from which they can easily be separated. A sharp look-out must be kept for abnormal vessels passing *towards the gall-bladder*, they must be caught

before being divided, as bleeding interferes with the clear view that is necessary. The dissection is now continued until the three ducts are plainly seen, and *in no circumstances must forceps or ligature be applied to the cystic duct until all three can be recognized beyond all question.* In the majority of cases not much difficulty will be experienced. Probably the common duct will first come into view, then the cystic, and above the two the hepatic duct can be recognized. (Fig. 392.) In the conditions which demand this operation, the parts around the cystic duct are often thickened from œdema or chronic inflammation, and a good

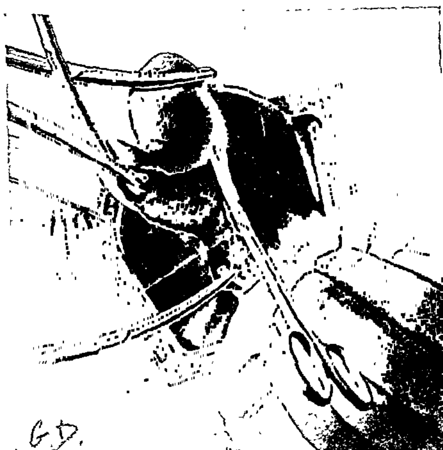


Fig. 393.—Cholecystectomy : third stage.

The cystic duct has been divided, and also the artery. The gall-bladder is being separated from its bed.

deal of tissue may have to be separated before the duct itself is exposed. When seen it is closely examined, and care must be taken that there is room for the forceps, which are next to be applied below the last stone and between it and the junction of the cystic with the common duct. Some surgeons prefer to isolate the duct by blunt dissection with an aneurysm needle and to use this instrument for passing the ligature around the duct. It is extremely important to ensure that no portion of the common duct is unwittingly cut away. In ordinary cases it is not essential to take away the whole of the cystic duct, so long as it is divided below any impacted stone or stricture If necessary because of the site of impaction of the stone,

the cystic duct may be cut off flush with the common duct, but in that case a tube will have to be passed down into the common duct or placed over the opening in it. (Fig. 395.) The cystic duct should not be divided until it has been clamped or ligatured, as it may retract, and may not easily be found again, and bile leakage will be inevitable for a considerable time. The duct having been divided, the separation

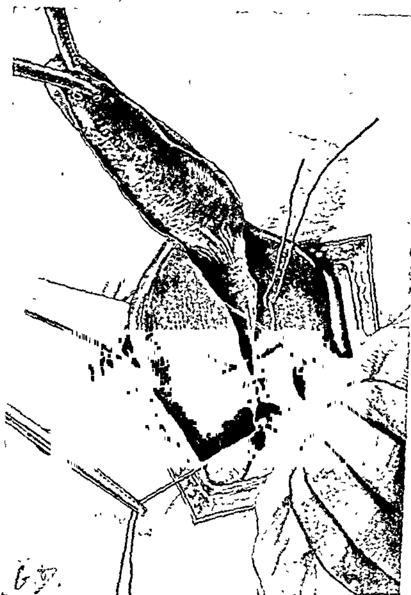


Fig. 394.—Cholecystectomy : fourth stage.
The cystic duct has been ligatured, the gall bladder is left attached at the fundus as a tractor while its bed is being closed by interrupted sutures.

with scissors or forceps is continued until the cystic artery is seen above and to the inner side of the duct, where it is caught in forceps; it is best tied and the ligature cut short at once, lest it be pulled off in the subsequent manipulations (Fig. 393.) The gall-bladder is then gently drawn upwards away from the ducts.

When the viscus has been separated for about a third of the required amount, it is left as a handle while the stump of the duct is dealt with. As a rule this should be ligatured, but it may be utilized for drainage; or it may be dilated with a pair of forceps until it will admit a tube passed into the hepatic duct; or the common duct may be opened by slitting the cystic duct right down into it. If the duct is to be tied, it is safer to apply two ligatures, one below the clamp and one to the extremity of the duct, which is caught in another artery forceps for that purpose. The former ligature is left

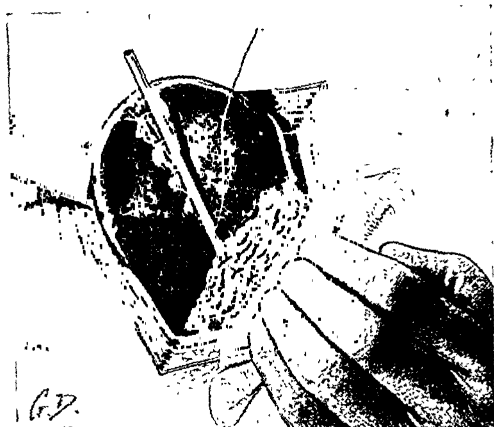


Fig. 395.—Cholecystectomy completed.

long at this stage. Any bleeding about the stump is now dealt with and the separation of the gall-bladder from the liver completed. This is usually very easy, but may require the aid of the scissors. It is necessary, however, to keep in the proper plane, or the liver tissue may be much torn. One or two vessels will have to be caught. The bed from which the viscus has been removed may be closed with a suture here and there (Fig. 394), or by a continuous stitch if it is surrounded by a sufficient peritoneal fringe; or it may be merely a deep sulcus in the liver, the edges lying together without the aid of sutures. Some venous bleeding may occur and be due to passive

congestion of the part of the liver withdrawn from the abdomen; if so, it will stop as soon as the liver is allowed to return to its normal position. In all cases a small soft tube ($\frac{1}{4}$ in. in diameter) should be brought from the neighbourhood of the divided duct as a safeguard. Occasionally there is bile leakage almost at once, probably the result of some small tear into one of the ducts which has been made during the process of separation, or to the division of some small accessory duct opening directly into the gall-bladder. Leakage several days after operation results from too early absorption of the catgut ligature or from infection. Some operators close the abdomen without making provision for bile drainage, but in that case the stump of the cystic duct is very carefully buried by placing peritoneum and cellular

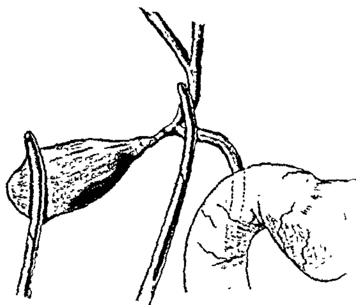


Fig. 396.—Illustrating one way in which the common bile-duct may be injured during cholecystectomy.
(Modified from Kehr)

tissue about it. It is much sounder practice to leave in a small tube. The ligature on the cystic duct which has been left long should be threaded on a needle and passed through the wall of the drainage tube from its lumen. On this the tube is guided down to the proper site, and is held there until the packs are removed and the abdomen is about to be closed. If it has been impossible to cover in the gall-bladder bed, or if there is a raw area about the neck of the gall-bladder, this may be protected (i e. from adhesion of viscera) by the small omentum and neighbouring fat, which can be drawn over it, as shown in Fig. 395.

Removal of the gall-bladder commencing at the fundus.—This method is forced upon the surgeon in those cases where a very tense gall-bladder has only a limited attachment to the liver, which gives way the moment the viscus is handled. It may also be expedient when the gall-bladder has a distinct mesentery, or when it is so small,

shrivelled, and rigid that it can scarcely be manipulated until freed from its bed. Whenever this method has to be adopted, the one essential is to isolate the cystic duct and to demonstrate its relation to the hepatic and common duct *before* it is divided. The temptation is to make traction on the gall-bladder and to treat the region of the neck like a pedicle.* There is then a great risk of injury to the deeper ducts, as shown in Fig. 396. It is surprising to find how often this accident has happened, even in the hands of experienced surgeons. Hæmorrhage from the liver-bed may be troublesome because the

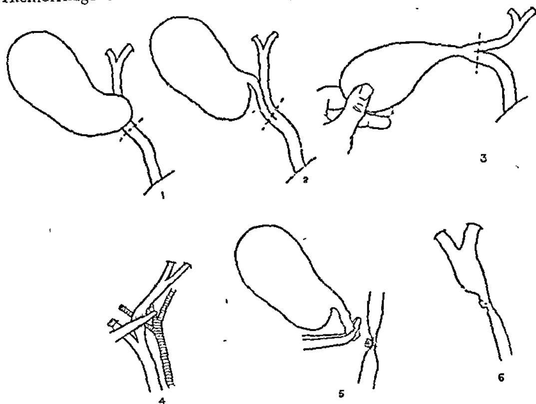


Fig. 397.—Some of the various ways in which the common duct may be injured.

1 The pouch of Hartmann overlies the junction of the ducts and the common duct is mistaken for the cyst-
2 Cystic and common duct run side by side
to be drawn up as a loop 4 Injury by a
5 The stump of the cystic duct is much t
gall-bladder, the inflammatory process

branches of the cystic artery are divided before the main trunk is dealt with, it should be controlled by suture or ligature while the gall-bladder remains as a convenient handle.

After-treatment.—In the great majority of cases there will be no bile leakage. The tube need not be removed until the time of the first dressing, at the end of a week. Recovery is usually easy and satisfactory and patients are able to leave bed in two or three weeks.

Difficulties and complications.—These are nearly all connected with injury to the ducts, and attention must again be drawn to the anomalies of the cystic duct and to the necessity of identifying by

* Hans Kehr, "Die Praxis der Gallenwege, Chirurgie in Wort und Bild," 1913.

congestion of the part of the liver withdrawn from the abdomen; if so, it will stop as soon as the liver is allowed to return to its normal position. In all cases a small soft tube ($\frac{1}{4}$ in. in diameter) should be brought from the neighbourhood of the divided duct as a safeguard. Occasionally there is bile leakage almost at once, probably the result of some small tear into one of the ducts which has been made during the process of separation, or to the division of some small accessory duct opening directly into the gall-bladder. Leakage several days after operation results from too early absorption of the catgut ligature or from infection. Some operators close the abdomen without making provision for bile drainage, but in that case the stump of the cystic duct is very carefully buried by placing peritoneum and cellular

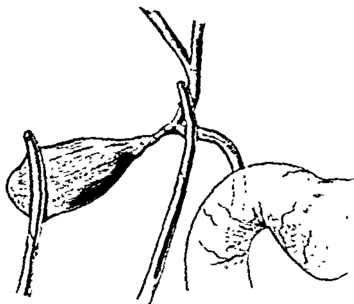


Fig. 396.—Illustrating one way in which the common bile-duct may be injured during cholecystectomy.
(Modified from Kehr)

tissue about it. It is much sounder practice to leave in a small tube. The ligature on the cystic duct which has been left long should be threaded on a needle and passed through the wall of the drainage tube from its lumen. On this the tube is guided down to the proper site, and is held there until the packs are removed and the abdomen is about to be closed. If it has been impossible to cover in the gall-bladder bed, or if there is a raw area about the neck of the gall-bladder, this may be protected (i.e. from adhesion of viscera) by the small omentum and neighbouring fat, which can be drawn over it, as shown in Fig. 395.

Removal of the gall-bladder commencing at the fundus.—This method is forced upon the surgeon in those cases where a very tense gall-bladder has only a limited attachment to the liver, which gives way the moment the viscus is handled. It may also be expedient when the gall-bladder has a distinct mesentery, or when it is so small,

shrivelled, and rigid that it can scarcely be manipulated until freed from its bed. Whenever this method has to be adopted, the one essential is to isolate the cystic duct and to demonstrate its relation to the hepatic and common duct *before* it is divided. The temptation is to make traction on the gall-bladder and to treat the region of the neck like a pedicle.* There is then a great risk of injury to the deeper ducts, as shown in Fig. 396. It is surprising to find how often this accident has happened, even in the hands of experienced surgeons. Hæmorrhage from the liver-bed may be troublesome because the

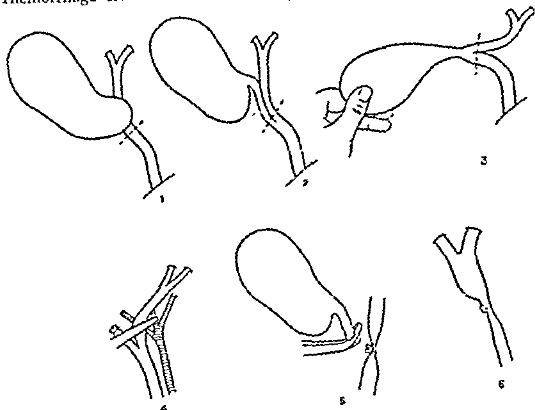


Fig. 397.—Some of the various ways in which the common duct may be injured.

branches of the cystic artery are divided before the main trunk is dealt with; it should be controlled by suture or ligature while the gall-bladder remains as a convenient handle.

After-treatment.—In the great majority of cases there will be no bile leakage. The tube need not be removed until the time of the first dressing, at the end of a week. Recovery is usually easy and satisfactory and patients are able to leave bed in two or three weeks.

Difficulties and complications.—These are nearly all connected with injury to the ducts, and attention must again be drawn to the anomalies of the cystic duct and to the necessity of identifying by

* Hans Kehr, "Die Praxis der Gallenwege, Chirurgie in Wort und Bild," 1913.

congestion of the part of the liver withdrawn from the abdomen; if so, it will stop as soon as the liver is allowed to return to its normal position. In all cases a small soft tube (¼ in. in diameter) should be brought from the neighbourhood of the divided duct as a safeguard. Occasionally there is bile leakage almost at once, probably the result of some small tear into one of the ducts which has been made during the process of separation, or to the division of some small accessory duct opening directly into the gall-bladder. Leakage several days after operation results from too early absorption of the catgut ligature or from infection. Some operators close the abdomen without making provision for bile drainage, but in that case the stump of the cystic duct is very carefully buried by placing peritoneum and cellular

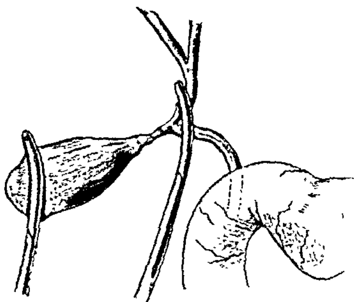


Fig. 396.—Illustrating one way in which the common bile-duct may be injured during cholecystectomy.
(Modified from Kehr.)

tissue about it. It is much sounder practice to leave in a small tube. The ligature on the cystic duct which has been left long should be threaded on a needle and passed through the wall of the drainage tube from its lumen. On this the tube is guided down to the proper site, and is held there until the packs are removed and the abdomen is about to be closed. If it has been impossible to cover in the gall-bladder bed, or if there is a raw area about the neck of the gall-bladder, this may be protected (i.e. from adhesion of viscera) by the small omentum and neighbouring fat, which can be drawn over it, as shown in Fig. 395

Removal of the gall-bladder commencing at the fundus.—This method is forced upon the surgeon in those cases where a very tense gall-bladder has only a limited attachment to the liver, which gives way the moment the viscus is handled. It may also be expedient when the gall-bladder has a distinct mesentery, or when it is so small,

shrivelled, and rigid that it can scarcely be manipulated until freed from its bed. Whenever this method has to be adopted, the one essential is to isolate the cystic duct and to demonstrate its relation to the hepatic and common duct *before* it is divided. The temptation is to make traction on the gall-bladder and to treat the region of the neck like a pedicle.* There is then a great risk of injury to the deeper ducts, as shown in Fig. 896. It is surprising to find how often this accident has happened, even in the hands of experienced surgeons. Hæmorrhage from the liver-bed may be troublesome because the

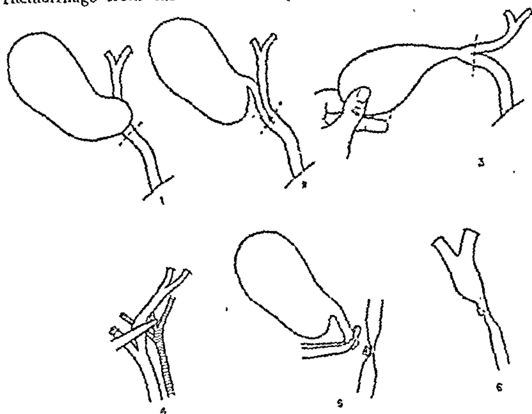


Fig. 397.—Some of the various ways in which the common duct may be injured.

1. The pouch of Hartmann overlies the junction of the ducts and the
2. Cystic and comm
to be drawn up as
5. The stump of th
gall bladder, t

branches of the cystic artery are divided before the main trunk is dealt with; it should be controlled by suture or ligature while the gall-bladder remains as a convenient handle.

After-treatment.—In the great majority of cases there will be no bile leakage. The tube need not be removed until the time of the first dressing, at the end of a week. Recovery is usually easy and satisfactory and patients are able to leave bed in two or three weeks.

Difficulties and complications.—These are nearly all connected with injury to the ducts, and attention must again be drawn to the anomalies of the cystic duct and to the necessity of identifying by

* Hans Kehr, "*Die Praxis der Gallenwege, Chirurgie in Wort und Bild,*" 1913.

sight all three ducts before the cystic duct is divided. The operator should either himself examine the gall-bladder as soon as it is removed or should get an assistant to do so and if there is any question of injury to the ducts, they should be examined at once so that the damage may be repaired while fresh (p. 965). The surgeon should realize that injury to the ducts is always potentially serious and that such accidents are a grievous reproach to surgery; the accident has often occured in the easy cases where the ducts are long or, at least, lax (Fig. 896). Prophylaxis must always be the golden rule. Another danger is from hæmorrhage. If this occurs, either from some uncaught vessel or because a ligature has slipped, it is necessary to see and to catch the individual vessel. Very often this cannot be done at the moment because the field is flooded with blood. In these circumstances the surgeon should rapidly apply a large forceps to the bleeding area for the purpose of temporarily arresting the hæmorrhage, and this may be used as a tractor by which the parts can be gently drawn towards the surface while the blood is sponged away and the actual vessel is found and separately caught and tied. Many accidents are due to the fact that a mass of tissue is hurriedly tied in thoughtless efforts to stop hæmorrhage. A still worse proceeding is to pass a needle deeply about unidentified structures, which are thus surrounded by a ligature and blindly occluded. Sometimes there may be very great difficulty in tying the vessel in the depths of the wound. In these circumstances no harm will come from leaving an artery forceps *in situ*, provided its grasp includes only the bleeding vessel. Such a forceps should be loosened in forty-eight hours, and removed a few hours later if there is no further bleeding.

Alternative Methods of dealing with the Gall-bladder when Complete Formal Excision is not Expedient

These methods are four in number :

1. Partial excision.
2. Removal of the mucous membrane only—subserous decortication.
3. Destruction of mucous membrane by cautery.
4. Electro-surgical obliteration.

1. **Partial excision.**—This may be limited to the fundus, or to the whole of the gall-bladder except its neck. The latter plan is to be used when there is special difficulty in exposing the parts about the neck, or when this exposure has disclosed some condition of the ducts contra-indicating the usual type of removal If the cystic duct is patent, as shown by the escape of bile or the facility with which a probe can be made to traverse the duct, it is not necessary to do anything more than partial suture of the divided viscus. A tube should be brought from the stump of the gall-bladder, after having first placed one or two sutures in the gall-bladder bed. If, on the

other hand, there is any question about the patency of the duct, the remains of the mucous membrane should be dissected away, or should be destroyed by the cautery. In either case a tube must be brought from the stump to the surface.

2. **Removal of the mucous membrane.**—When the gall-bladder is embedded in the substance of the liver, or is buried in a dense mass of adhesions, it may be impossible to carry out a formal excision. In these circumstances an attempt may be made to remove the mucous membrane entire. After the contents of the viscus have been dealt with, a longitudinal incision is made along the under-surface of the gall-bladder down to the submucous coat. The lining membrane is then separated by blunt dissection and gentle traction. After thorough separation a ligature must be applied to its neck and a tube brought from this point up through the remaining coats of the gall-bladder to the surface. There will be some little hæmorrhage from the inner surface of the outer coats, which must be dealt with either by obliterating sutures or by gauze packing. It is seldom possible to carry out this plan and one of the following methods have usually to be employed instead or used in combination.

3. **Destruction of the mucous membrane by the actual cautery** (Rutherford Morison).—This method may be employed when the others are not available. The gall-bladder is first emptied and is then split along its inferior surface from fundus to neck and, after being thoroughly dried, the secreting part of the mucous membrane is destroyed with the thermo-cautery. The walls are then drawn together with catgut sutures in such a way as to obliterate the cavity, or, if they are too thickened and rigid, the cavity is packed with gauze.

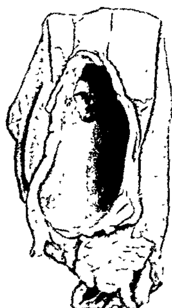
4. **Electro-surgical obliteration.**—In this method the gall-bladder is laid open from fundus to neck and the mucous membrane thoroughly and completely destroyed by electro-coagulation. The halves of the viscus are then sewn together and the abdomen closed without drainage. The idea is to avoid the risk of hæmorrhage and spread of infection by destroying the inner layers of the gall-bladder without opening up the cellular tissue between the viscus and the liver. The serous layer is preserved and used as a covering for the treated area.

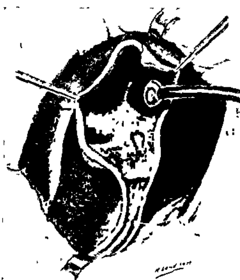
The depth and extent of the coagulation can be regulated by the strength of the current, the type of the electrode and the pressure with which it is applied When the wall of the gall-bladder is very thick or an abscess has extended into the liver, deep coagulation will be necessary. Aseptic necrosis results and healing is satisfactory. This method has recently been strongly advocated by several surgeons.* Pribram has had personal experience of more than a thousand cases of all types treated in this way and with very good results. It is claimed that, as drainage is dispensed with, there is very little post-operative discomfort and recovery is rapid and complete. It is stated that the

* *Lancet*, Oct. 28, 1939, ii, 927.

method is particularly suitable for cases with suppuration and especially when there is extension of the inflammatory process to the liver.

Technique.—The gall-bladder is exposed by any convenient incision. Proper exploration of the extent of the disease and of the condition of the deeper ducts is the first step. The operation area must then be walled off with wet saline packs. If the gall-bladder is voluminous it is aspirated, after which the cystic duct is exposed, divided and ligatured in the usual manner. When easy of access, the cystic artery should also be ligatured. The gall-bladder is then laid open along its whole length, and the contents evacuated. After being thoroughly





A B

Fig. 398 A.—Acute infection of gall-bladder with ulceration into liver.
B.—Electro-surgical obliteration of gall-bladder.
(*Reproduced by permission from the Lancet, 1939, Oct 28*)

dried, the whole of the mucous membrane is destroyed by electric coagulation (Fig. 398B) and the walls are then sutured together, thus leaving a smooth serous surface. When there is inflammatory extension into the liver or there are fistulæ into the stomach or bowel, the viscera are not separated, but any track into the liver (Fig 398A) or the orifice of a fistula is thoroughly coagulated and the remainder of the viscus dealt with as described

Another plan (Thorek) is to cut away the redundant part of the gall-bladder, leaving only that area which is attached to the liver to be treated by electro-coagulation This is then covered over by a detached piece of the triangular ligament or a free omental graft sutured in position In both methods the abdomen is closed without drainage

Enthusiasts urge that this method should be adopted in place of cholecystectomy and not simply kept in reserve as an alternative plan. It probably has a considerable field of usefulness in dealing with acute

and badly infected cases, but there is no doubt that its advocates have exaggerated the alleged disadvantages of the occasional cholecystotomy or the more usual cholecystectomy, which in expert hands are thoroughly satisfactory operations.

Special points in the removal of the gall-bladder for cancer.—The preliminary examination is most important, for the surgeon must



Fig. 399.—Malignant gall-bladder with calculi fungating into colon. Good immediate recovery following cholecystectomy with partial hepatectomy and colectomy with end-to-end anastomosis. Local recurrence seven months later with death soon afterwards.

take special care to see that there are no secondary deposits in the liver. Direct extension to the latter does not always contra-indicate operation, but in the presence of scattered secondary deposits, removal of the gall-bladder is useless. It is also important to examine the ducts, as extension in this direction may make removal impossible. Some surgeons advise that in all cases a wedge resection of the liver should be carried out (*see* p. 896). Direct involvement of the colon does not necessarily contra-indicate radical operation, but it does mean that

partial colectomy will be required in addition to the cholecystectomy. If the gall-bladder cannot be removed it should on no account be opened, unless there is some such complication as *empyema*, for this proceeding does not relieve symptoms; a mucous or biliary fistula invariably persists, and the growth is apt to fungate through the sinus.

Results of operations for cancer of the gall-bladder.—The primary mortality is probably about 10 per cent. In cases that are recognized



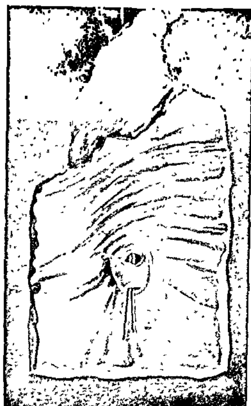


Fig 400A *Fig. 400B*

Diagrams made from actual specimens of calculi in the common duct.

Fig. 400A.—Calculus impacted in the pancreatic portion of the duct, in a position suitable for removal by transduodenal choledochotomy.

Fig. 400B.—*Showing how a calculus impacted in the same situation has ulcerated* into the duodenum through the side of the duct, the papilla remaining intact. *(Guy's Hospital Museum)*

as frankly malignant by the naked eye at the time of the interference, the ultimate prognosis is very bad, for the great majority die from recurrence within twelve months. On the other hand, when the condition is discovered fortuitously as the result of microscopic examination of the excised gall-bladder, the results are much more favourable, and this is one of the strong arguments in favour of cholecystectomy.*

CHOLEDOCHOTOMY

The common duct may be opened in any of its three parts, and the operation employed in each case has needlessly attained the dignity

* Samburg and Garlode, *Surgery*, 1948, xxiii, 201

of a special name. Attention must be drawn to the anatomy of the duct, as shown in Fig. 869, p. 874. The illustrations showing the relations of calculi to the various parts of the duct emphasize some of the technical difficulties. (Figs. 400A and B.) Lymphatic vessels and some lymph nodes lie along the course of the common duct, and the latter, when enlarged and especially if calcareous, may closely simulate calculi in the duct. The dilatation of the ducts varies within wide limits, and the lumen may be like that of the small intestine, or just large enough to admit the Desjardin forceps. The thickness of the wall is also very variable, for it may be so thin that the bile can be seen through it, or so thickened that it is quite difficult to cut into the lumen. It must be clearly realized that the supraduodenal portion of the duct is frequently much obscured by pathological changes. *The infundibulum of the* gall-bladder is often adherent to the duodenum, and the latter is frequently drawn up over the duct by other adhesions. When these are separated the duct comes into view and, by pressing the duodenum and pancreas downwards, an exposure of the supraduodenal part of the duct beyond its anatomical limits can easily be obtained. This exposure is further enhanced by the use of the loin support, and, in occasional circumstances, it may be made still more accessible by mobilization of the duodenum (Kocher). This is carried out by gently tearing through or incising the peritoneum just to the outer side of the duodenum as it lies over the right kidney. It is enough to make quite a small opening in this membrane, as the remainder of the mobilization can be done by blunt dissection with the fingers, which easily manipulate the duodenum forwards and inwards. The incision of the supraduodenal or free portion of the duct is undoubtedly the operation of choice, and in the great majority of cases the calculi can be removed from this part.

Special preparation.—This is very important, but has been sufficiently dealt with at p. 910.

Technique.—In many of the cases jaundice will be a complication, and will demand the gentlest manipulations and the most scrupulous regard for hæmorrhage, even the smallest vessels being caught and tied. This precaution applies to the parietal wound as well as to the deeper parts The abdominal incision must be adequate, and all the additional aids to exposure will have to be employed. In very fat subjects none of these aids will make the operation an easy one. A headlight may be very useful. The steps are as follows :—

1. General exploration and palpation of ducts.
2. Exposure of the common duct.
3. Incision of the duct.
4. Extraction of calculi and exploration of ducts from within.
5. Treatment of the gall-bladder.
6. Arrangements for drainage.
7. *Toilet and wound closure.*

As a first step the gall-bladder is examined, and, if it contains stones, the decision as to their treatment will be made ; but it is better to deal with them after the common-duct part of the operation is over, as the viscus forms a convenient handle and a safe means of making traction on the duct, thus helping to bring it nearer the surface and to straighten it. The gall-bladder is also the best guide to the duct Among the numerous adhesions to the omentum and to neighbouring viscera, the surgeon must be on the look-out for internal fistulæ, which may be

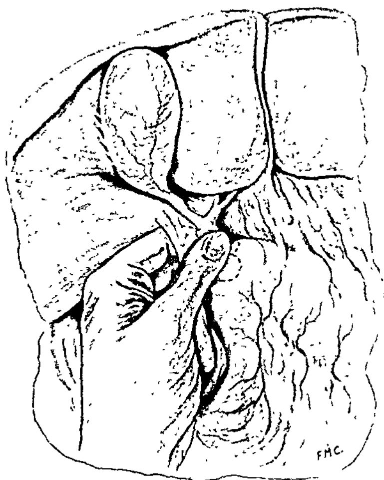


Fig. 401.—Method of palpating common duct with the left hand.

hidden in an adhesion of the infundibuliform type (Fig. 387, p 924). These must be separated before the common duct can be exposed. In jaundiced cases the gall-bladder is usually small and shrivelled, but it may be voluminous and may further obscure the parts, when it must be emptied as a preliminary. Occasionally the gall-bladder is so much shrivelled from previous inflammation that it is practically non-existent. In these circumstances it is of very little value as a guide to the duct, and certainly cannot be used as a tractor. Again, the duct may be so obscured from adhesions that its exposure is long and tedious and produces much traumatism. In either of these circumstances it

may be possible to rotate the duct, as pointed out by Moynihan.* The manœuvre is carried out by the fingers of the left hand which are passed along the gastro-hepatic omentum just above the pylorus and stomach. As the fingers are flexed, the hand and wrist are bent over to the patient's left. In this way the posterior surface is exposed and may be incised. When the common duct is exposed as it lies in the edge of the small omentum it can be palpated between the first two fingers of the right hand in the foramen of Winslow and the thumb in front. This can often be most conveniently done if the surgeon stands on the opposite (left) side of the patient. (Fig. 401.) To palpate the whole duct, the head of the pancreas and duodenum must also be felt in the same way. If the presence of stones is confirmed, it must be determined whether they are movable in the duct or fixed. If they are free, care must be taken that they do not slip up into the hepatic ducts out of reach. If they are fixed in the duct behind the duodenum, the surgeon must endeavour to manipulate them either into the supraduodenal portion of the duct or into the bowel. This is done by steady pressure on the lowest part of the stone, and in this manipulation considerable force may be used, provided great care is taken not to pull or push on the duct in such a way as to cause tearing. A process of "coaxing" is often the most successful This examination will probably determine where the duct is to be opened, and in the great majority of cases the supraduodenal portion will first have to be incised.

(1) **The supraduodenal operation.**—Packs are arranged (*a*) in front of the small omentum to keep back the stomach ; (*b*) below to control the duodenum and colon, and (*c*) in the hepatic pouch to catch any of the contents of the duct that may escape in that direction. The liver is held aside by an assistant who also makes gentle traction on the gall-bladder. Adhesions having been separated as described, and the duodenum pushed well down, the duct is now exposed by gently tearing through the overlying peritoneum with dissecting forceps. Where exposure is difficult it will be an aid at this stage gently to lift the duct forwards by the fingers of the left hand in the foramen of Winslow. Sometimes the parts about the duct are so thickened or infiltrated that they will not strip, but often in these circumstances the forceps happen to tear into the duct and disclose its lumen Occasionally it is not possible to identify the duct except by incision ; in this case the greatest care must be taken not to carry the knife by the side of the duct straight into the portal vein or even through the duct into the vein. When there is great difficulty in identifying the duct, it may help to use a small exploring syringe. When all else fails, the gall-bladder and cystic duct may have to be slit up until the lumen of the common duct is reached.

The duct having been exposed, the next step is to secure it on either side of the proposed incision, either in catch forceps or with a catgut stitch the ends of which are left long to be used as guys. While it is

* "Abdominal Operations," vol ii, 3rd edn.

steadied by traction on the forceps or sutures, a longitudinal incision is made into its lumen. The incision must be large enough to give exit to the stone or admit the forceps necessary for its extraction. It will seldom be less than half an inch in the first instance, and if necessary may be conveniently enlarged upwards by fine-pointed scissors Care must be taken not to injure vessels which may cross the duct (Fig. 397). Any that are seen should be caught, divided between forceps and ligatured. The escape of bile at once identifies the lumen, but sometimes the content is only clear mucus, and this is often so in cases of long-standing obstruction. If the secretion has been dammed up, there may be a considerable quantity which must be soaked up by gauze or removed by suction.

If the stone is just at the site of the incision, it may escape or be easily extruded by manipulation, or it may be caught in forceps and extracted. An elusive stone is sometimes very difficult to locate, and when such a stone is felt it is best to fix it between the finger and thumb and to cut directly on to it, sutures or catch forceps being placed in the wall of the duct after the incision is made. Or it may be easier to catch the portion of duct containing the stone in a pair of long ring-forceps, thus leaving the fingers free for other manipulations. Whenever possible, the lumen of the duct is explored by the finger, which is the most reliable probe. At the present day, operations for obstructive jaundice are carried out at a much earlier stage than formerly and the ducts have usually not had time to get sufficiently dilated to admit the finger. In these circumstances, suitable forceps must be passed both downwards (Fig. 402) and upwards, and if any difficulty is experienced in dislodging calculi, and always when there is débris, the gall-stone scoop should be used. Very small stones, fragments of larger calculi or bile sand are removed by packing a small strand of gauze or a tape into the duct and slowly withdrawing it, when the stones will often be found entangled. There is sometimes a lateral pouching of the lower end of the common duct in which stones or débris may be hidden, and the scoop is most likely to remove them, or the débris may be extracted entangled in the strand or ribbon of gauze. Very small calculi or fragments of calculi may sometimes be removed by irrigation with warm normal saline. For this purpose the old fashioned Higginson's syringe with a soft tapering rubber nozzle will be found most convenient. Used with intelligence this syringe is an accurate instrument. The nozzle may be held in the duct and considerable pressure used so that when it is removed the fluid comes away under tension, the calculi or fragments escaping with it. A fine rubber catheter may be inserted into the ducts (both down and up) and irrigation carried out through its lumen, the edges of the incision into the duct being held open to facilitate return of the fluid. Sometimes the very free passage of the saline into the bowel demonstrates that the duct is quite clear. Cholangiography during the course of operation has been extolled by some surgeons but the writer has never been convinced of its value, an opinion shared by other experienced

surgeons.* In any case, it is best to pass a sound, $\frac{3}{16}$ in. in diameter (a Lister's bougie answers the purpose very well), along the duct into the duodenum, for the surgeon may then feel assured that any fragments which have evaded his search will safely pass into the bowel. If it has not been possible to extract the stone by combined use of the forceps and manipulation, it should not be broken, but some other route for its removal should be chosen.

The stone having been extracted, drainage must be arranged, as the consensus of experience is against complete closure of the duct by suture. If there is (*a*) jaundice of long standing; (*b*) much detritus in the duct; (*c*) clinical or other evidence of bile sepsis, or (*d*) any question about the duct being cleared of stones, then it should be drained by a tube passed into its lumen towards the hepatic duct. The proper type of tube to use is shown in Fig. 381, A, p. 918. Its end should be cut obliquely so as to expose as much of its lumen as possible, and in addition there should be a lateral hole. A No. 10 or 12 Jacques catheter with the end cut off serves the purpose very well. The incision in the duct should be closed by interrupted sutures up to the point where the tube emerges. The T-shaped tube so often recommended is not advised, for if it is left for more than a few days it cannot be removed without tearing the incision in the duct and there is a risk that the end piece may break off and be left in the duct. In most cases drainage of the interior of the duct is not necessary but the incision in its wall should be drawn together by a few interrupted sutures, great care being taken not to narrow the lumen. Exact closure is not necessary. As some bile leakage is almost certain, a small soft tube ($\frac{1}{4}$ in. diam.) should be threaded down to the duct on the end of one of the sutures in the way indicated for cholecystectomy or after suture of the duct. (Fig. 405, p. 965.) While the succeeding steps of the operation are being carried out, the tube is temporarily held *in situ* either by a

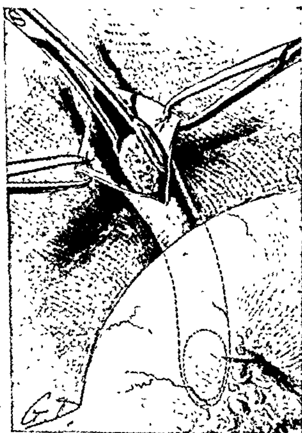


Fig. 402.—Removal of stone from lower end of common duct with the Desjardins forceps. (*Modified from Kehr.*)

* Priestley, Collected Papers Mayo Clinic, xli, 1949.

catgut suture tied over but not through it, or else by a forceps caught on the edge of the duct.

The gall-bladder is now dealt with according to the indications, remembering that in jaundiced cases it should not be removed. This conservative attitude is dictated by the necessity of reducing the risk of hæmorrhage and because it is among the common duct cases that recurrences or relapses are the more frequent. Subsequent operations on the common duct are greatly facilitated if the gall-bladder remains as a guide. Should there be a consequent pancreatitis the viscus may be invaluable for cholecystenterostomy. Since drainage from the duct or its neighbourhood has been provided, it is not usually necessary to drain the gall-bladder independently, though this may be done as the simplest way of finishing the operation. If there has been much bleeding, and oozing persists absorbable gauze or an ordinary gauze strand had better be packed over the area where the duct has been bared, and in any event a soft rubber tube or tissue drain should be brought from the hepatic pouch. Any exposed gauze is protected from contact with the viscera by rubber tissue, and the drains are brought from the abdominal wound together. The gauze and hepatic-pouch drain are cut short, and the common-duct tube is fixed to the skin by a silkworm stitch and carried through the dressings into a baby's feeding-bottle. (*See* Fig. 382, p. 919.)

(2) **The retroduodenal route.**—This is only to be employed when a calculus is so firmly impacted in the second part of the duct that it cannot be manipulated downwards into the duodenum or upwards into an accessible position in the first part of the duct, or removed by suitable forceps through a supraduodenal incision In actual practice this method is very rarely necessary, and it becomes less so as, with increasing experience, the means of thorough exposure of the supraduodenal part are better understood. The success of the operation depends on the thorough mobilization of the duodenum. This is carried out by incising the peritoneum on its outer side and then gently separating it inwards. In this way the duodenum and head of the pancreas can be rotated until their posterior surface is exposed. If the duct has been opened above, a sound may be passed downwards to act as a guide. There is, however, little difficulty in identifying the duct, since the impacted stone is a sufficient guide. The duct over the stone may be caught in catch forceps and then incised longitudinally. During this step the pancreas may have to be incised. After the extraction of the stone the duct is explored as already described. If there is also an opening in the supraduodenal part, drainage is better carried out from it; otherwise the tube may be introduced into the retroduodenal opening or brought from its margin. If not to be used for drainage, the opening in the duct is closed by three or four interrupted sutures of fine chromic catgut which do not enter the lumen. In any event, a soft rubber drain is brought from the vicinity Provided drainage from the neighbourhood of the incised duct is arranged, there need be no anxiety about suturing the duct, for the edges tend to

lie together when the parts are allowed to fall into position. None the less, the edges of a large opening in the duct should be drawn together by at least a single suture. The duodenum and head of the pancreas readily resume their former position, and do not require fixation.

(3) **The transduodenal operation.**—This is only to be used when a calculus at the lowest part of the duct cannot be removed with forceps from above or manipulated into the duodenum by pressure with the fingers, or pushed into the bowel with a sound. In actual practice it is very rarely required, which is fortunate, for it is not a very satisfactory operation.

The duodenum is isolated and brought into the wound, and if this cannot be done easily it should be mobilized for the purpose. The bowel is packed round with gauze, and an incision about 1½ in. long is made in its long axis opposite the middle of its second part. At the conclusion of the operation this incision is carefully sutured in the *opposite* direction, to obviate narrowing. If the bowel is voluminous the original incision may be transverse. The incision in the duodenum is held open by catch forceps or stay sutures and the orifice of the duct on the inner wall is either seen or is first identified by touch. The papilla may be disappointingly difficult to locate. When found, it may conveniently be drawn up into the wound and thus made more accessible. A catch forceps or catgut stitch is used for this purpose, but must take a deep hold of the bowel wall; otherwise it readily cuts out. If the stone is actually arrested at the orifice, it may be removed by simply incising the latter; but if it is impacted a little higher up, the inner wall of the bowel and the duct must be divided directly over it. (Fig. 400.) Steps must be taken to prevent the stone slipping back into the dilated duct above, and in any event, after its removal, the duct must be cleared by forceps and scoop or gauze. If the opening made in the duct is large, it may be closed if the normal orifice is sufficiently patent If there is any doubt about the patency of the orifice, or if the duct contains much débris, the incision should merely be diminished by one or two sutures passed through both the wall of the duodenum and the duct or left open. The actual orifice must be left larger than normal, so that drainage may be free and there may be no contraction during healing. If there is hæmorrhage, it may be controlled by stitching the wall of the duct to the wall of the duodenum at one or two points

After-treatment.—Any gauze and the drain from the hepatic pouch should be removed on the fourth day. The common-duct tube must remain for at least a week, and after its removal bile will discharge for perhaps another week. The complications and sequelæ are those associated with any jaundiced case, and the best prophylactic is free bile drainage, though excessive loss of bile may be deleterious (*see* p. 926).

Special difficulties of choledochotomy.—In fat and bulky patients this operation may be extremely difficult and hazardous. The most important point is to secure good exposure. The guide to the duct is the foramen of Winslow, and even when this is obliterated by adhesions, its situation marks the lateral or outer limit of the small omentum in which the duct lies. *The downward separation of the duodenum* is the next most helpful step. The surgeon must never incise what he takes to be the duct, until he has satisfied himself that the structure is in the position in which the duct normally lies. Identification may be greatly aided by cautious use of the hypodermic syringe. A fine needle may be inserted obliquely backwards and upwards in the position of the duct, while at the same time the plunger is withdrawn. *It must be remembered that in long standing cases* the content of the duct is often clear, the so-called "white bile". Care must be taken not to thrust the needle right through the duct into the portal vein. Even when the duct is properly identified and exposed, there may be difficulty in determining whether a nodule felt is really a stone. This difficulty is especially great when the suspected nodule is in the second or third part of the duct. The only safe rule *is to incise right up to any lump the nature of which cannot be otherwise* determined. Chronic inflammatory thickening of the wall of the duct, a localized pancreatitis, or a new growth of the duct or the ampulla, are the conditions most likely to lead to errors.

Removal of Calculi from the Hepatic Ducts

It is not necessary to give this operation any special name. Calculi may be firmly impacted in the hepatic ducts, but more commonly they are free, and either slip up from the common duct or are found when the latter is explored. When impacted they may be coaxed down into the common duct, or an incision may have to be made directly over them When free they may be washed out by the first rush of bile, or they may be caught with the Desjardins forceps. When they are known to have slipped out of reach, or can be felt but not withdrawn, *they may be coaxed down by using the forefinger like a piston* (Mayo). If there is any doubt about the hepatic duct being cleared it is essential to pass as large a tube as possible well into its lumen for drainage and thus to encourage the subsequent escape of calculi.

Other Methods Useful in Duct Surgery

Cholangiography and ether instillation.—Cholangiography is a diagnostic method in which some radio-opaque substance is injected into the biliary tract. This is done through a tube, like a catheter, size 8 or 10, which is passed into the common duct towards its lower end where obstruction is likely to persist. The duct must be closed firmly round about the tube by suture.

As a rule lipiodol is employed , it should be warmed and injected slowly into the common duct while observations are made with the *fluorescent screen* at regular intervals. Mirizzi (1931) and others

have used this method during the course of operation and designated the plan " operative cholangiography ". As a rule it is employed as a secondary diagnostic procedure a week or ten days after a tube has been inserted into the duct as part of the operation of choledochotomy. By this means information may be obtained of the presence, site and sometimes the nature of a persisting obstruction. It requires patience, care and expert X-ray technique.

Pribram (1932), has shown that the instillation of ether into the duct may dissolve an obstructing calculus. The plan is advocated rather than retroduodenal or transduodenal choledochotomy as both these operations carry a mortality of about 20 per cent. The drain tube, fixed in the duct, must first be emptied of bile with a syringe, which is then emptied, washed out with ether and recharged and used to inject gently into the duct. As a rule only about ½ to 1 c.c. is injected at a sitting and only drop by drop. If too much is used the patient complains of a sense of internal fulness or pressure. When the patient is comfortable, 1 or 2 c.c. of liquid paraffin are introduced into the tube, which is then clamped and left so for as long as the patient is at ease. The procedure may be repeated every day. At the end of a week a further cholangiogram is made and treatment carried on or otherwise as indicated.

Though some calculi dissolve readily the instillations may have to be carried on for as long as eight weeks to clear the duct. The cessation of biliary drainage or the appearance of bile in the stools suggest that the obstruction has disappeared, but it is essential to confirm the patency of the duct by repeating the cholangiography. By these methods Pribram (1939) claims that the mortality following the treatment of common duct stones has been reduced to 5 per cent. in his hands.*

Secondary operations on the biliary system.—These interventions should not be undertaken sooner than about three months after the primary operation. This allows a reasonable time for natural recovery while friability and abnormal vascularity will be lessened. In these circumstances great care should be exercised in proper preparation and in this respect laboratory co-operation is of great help. The main technical difficulty will be from the presence of adhesions, but though these may cause difficulties and embarrassment there are no cases in which they cannot be overcome by patient, careful work. When one of the vertical incisions has previously been employed it is often a great help to re-open the abdomen by the Kocher incision. In this way the parietal adhesions are avoided and the gall-bladder and ducts may be approached from above and it is often easier to find a plane of cleavage. The edge of the liver and the gall-bladder (if still present), or the notch for the gall-bladder are the first landmarks at which to aim.

The colon and the duodenum are often densely adherent to the gall-bladder site and the operator must be on the look-out for tears which may look trivial in the making but are usually uncomfortably large when they come to be repaired. Suture is best carried out as soon

* *Surgery*, vol. xxii, No. 5—806, 18, Nov., 1947.

as the part is sufficiently exposed. When the gall-bladder has been removed there is no sure guide to the common duct except a knowledge of its anatomical position. It may assist identification to put the fingers in the foramen of Winslow and gently lift forward the edge of the gastro-hepatic omentum. But very often the foramen is obliterated by adhesions, and in that event the duct can only be found by a fine exploring syringe.

When the necessary anatomical features are exposed, but not before the operation indicated can be carried out. I have found that secondary cholecystectomy is comparatively easy and satisfactory. Secondary operations on the ducts may be extremely difficult. Special care must be taken to control hæmorrhage and to guard against hepatic insufficiency during convalescence. It is perhaps in secondary operations on the ducts that cholangiography and the instillation of ether may find their greatest usefulness.

Complications and sequelæ.—Even in straightforward cases *hæmorrhage* and *escape of bile* into the peritoneum occasionally occur. A vessel which has retracted and escaped ligature or a punctured vein may account for considerable bleeding. In jaundiced patients it is remarkable how oozing may persist and account for serious blood loss. Sometimes the blood flows or is sucked over the dome of the liver and coagulates there. Quite a moderate collection in that situation tends to depress and rotate the liver and may cause a serious shock-like state.* Bile in the peritoneum has often been regarded as innocuous but it may certainly be otherwise and be the cause of rapid death.† The bile may flood the general peritoneum or accumulate over the dome of the liver or may occupy and distend the lesser sac. When symptoms and signs suggest that either of these conditions have occurred the incision must be opened up without delay. If bleeding is recent its source must be discovered and dealt with but if old, complete relief may follow evacuation of the accumulation. The same applies if the extravasation is bile for evacuation and drainage is all that is required. It may be necessary to make an additional opening in the supra-pubic region. Other complications are mentioned at page 939.

Results of operative interference with the gall-bladder and ducts.—In the majority of cases the operations will have been required for gall-stones or their complications, but the subject is inseparably connected with that of cholecystitis, and in a review of the results the surgical treatment of that condition must be included The subject may be considered under three heads :—

1. Immediate mortality.
2. The relief afforded
3. Recurrences

1 **The immediate mortality** depends for the most part on the condition demanding the operation When calculi are limited to the gall-bladder and unattended by complications, the mortality may be as

* Walters, *Lancet*, Aug 13, 1949 p 265
† Douglas and Grey Turner *B M J* Aug 31, 1940, p, 280

low as 1 per cent. or less, whereas in operations involving the common duct in the presence of jaundice, and with septic complications, it may be as high as 20 per cent. But even in cases most favourable from the pathological standpoint and where there is no question of complications, the general condition of the patient and the anatomical features have some bearing on the results. Many of those who require operations for gall-stones are elderly, they are often stout, the heart is apt to be fatty, and there is a tendency to bronchitis. It is a striking fact that the mortality among males is about twice as great as among females (Edington, Walters). All these features have an influence on the immediate results. Fortunately, with the onward march of surgery, operations for gall-stones are being carried out at a much earlier stage of the disease, and patients now frequently come to the surgeon when younger and in better condition. Nevertheless, the results finally depend on judgment in deciding on the stage of the illness at which to interfere on the care in preparation, on the selection of the proper procedure after the abdomen has been opened, on technical ability in carrying this out and on discerning after-care. Some surgeons have special opportunities of acquiring experience in this class of work, and have operated upon large numbers of cases with surprising results. During 1938, at the Mayo Clinic, 930 patients were subjected to cholecystectomy with a mortality of 1·8 per cent. There were also 308 operations for benign lesions of the bile-ducts with 6·5 per cent. of deaths; nearly half the patients in this group were jaundiced. But quite apart from the work of "specialists" in gall-bladder surgery the results are very good. Taking a continuous series of cases operated upon by a general surgeon, and reckoning all the various conditions and operations together, the mortality works out at not quite 6 per cent. In those cases in which the stones were limited to the gall-bladder, but including the complications which may occur in this situation, the percentage was 3 and for the common-duct cases nearly 14. In the hands of ordinary competent surgeons at the present time the mortality of operations for gall-stones with their complications, when limited to the gall-bladder, should not be more than about 1 per cent., when they have invaded the common duct, about 3 per cent. or, if jaundice is present, 5 per cent. While this section does not attempt to deal with the comparative mortality of the individual operations which have been employed, it is permissible to state that cholecystectomy when properly indicated and carefully carried out is one of the most satisfactory operations in abdominal surgery. In the hands of many surgeons the immediate mortality has been considerably less than 1 per cent., the morbidity slight, and the after results completely satisfactory in over 90 per cent. of cases. The one blot on the record is the occasional injury to one of the deeper ducts, a serious accident which has assumed alarming frequency in some other countries to the discredit of surgery.

2, 3. **Relief afforded, and Recurrences.**—In some cases persistent symptoms are due to pre-existing disease of the stomach or duodenum.

or to chronic appendicitis or cirrhosis of the liver. Very rarely, stomach symptoms developing after operation are due to adhesion of the pyloric region to the gall-bladder area, which is an argument for its proper protection after cholecystectomy. There are also cases in which recurrence of symptoms follows rapidly on an operation of expediency, carried out because the condition of the patient was not such as to justify those measures which the pathological condition indicated. Such events cannot be looked upon as recurrences, though they appear so to the patient. Even when the operation performed has been properly indicated and carried out, about 10 per cent. of the patients complain of recurrence or persistence of symptoms. These patients can be divided into two groups—(1) those who have never experienced complete relief, and (2) those who have been well for a varying period and have then had a return of symptoms.

In the *first group* the commonest causes are calculi left behind, pancreatitis, ... ducts. Fully develo... likely to be overloo... ,... stening gall-bladder, which is the type that often harbours early cancer, may readily be left unless cholecystectomy is frequently practised. Overlooked *calculi usually lurk in the common duct, and especially in cases* in which there has been long-standing obstruction, and in which lateral pouching of the duct has developed. In some of the cases, calculi *found at a second operation have probably been lying in the hepatic* ducts, from which they have been flushed into their new position. When in the gall-bladder they will be found about the neck or in the cystic duct. Some degree of pancreatitis is present in about 20 per cent. of the common-duct cases, and persistence of the infection in the duct presumably lights it up again Stricture of the ducts is a condition which may be anticipated if there has been difficulty in carrying out excision of the gall-bladder. There will usually have been suggestive symptoms during the immediate convalescence, so that it is not likely to develop as a surprise.

In the *second group*, in a series of cases analysed by Judd of the Mayo Clinic, the interval of complete relief averaged two and a half years, but recurrence may follow ten or twelve or more years after the primary operation. In this group there is usually recurrence of stones. It may be due to the persistence of the original infection, or stones may form around some fragment or fragments left behind, or around a foreign body such as a suture (Fig. 888, p. 925). The persistence of the primary infection is illustrated by cases in which, at the original operation, the gall-bladder showed evidence of gross infection but without stones, whereas at the second operation stones were found. Recurrence of calculi is usually limited to cases in which the gall-bladder has only been drained at the original operation, and is one of the strong arguments in favour of removal of the gall-bladder rather than simple drainage In fact, recurrent symptoms of all sorts are much more frequent after the drainage operation, and are due to a

persistence of the biliary infection, or to a fresh cholecystitis, or to a recurrence of calculi, or to cancer. After cholecystectomy symptoms may recur, but are then most likely to be due to pancreatitis, to overlooked or newly formed calculi in the ducts, or to adhesions to the site from which the gall-bladder has been removed. In a certain proportion of cases, further operation fails to explain the recurrence of symptoms, which are then probably due to some little-understood type of hepatitis. Repeated recurrence of calculi also takes place, and these rare cases have an interesting bearing on the question of the gall-stone diathesis. It has been suggested that this diathesis is the result of toxins which are elaborated in the spleen and excreted by the liver. Acting on this assumption, splenectomy has been deliberately practised to deal with such recurrences. Overlooked acholuric jaundice may be the explanation of some disappointing recurrences. The whole question of the after results has been carefully studied by James H. Saint, Pribram* and others.

OPERATIONS FOR OBSTRUCTIVE CONDITIONS NOT DUE TO CALCULI

The conditions that come under this head may be—

1. Chronic pancreatitis.
2. Malignant disease of the head of the pancreas.
3. Malignant disease of the bile-ducts,
4. Involvement of bile-duct in a new growth of the duodenum.
5. Obliteration or stricture of the ducts following injury.
6. Parasites—hydatids, roundworms, etc.

The association of jaundice with a distended gall-bladder is usually due to malignant disease of the head of the pancreas or to chronic pancreatitis. In the absence of signs of dissemination the diagnosis cannot be made with absolute certainty until the abdomen is opened, and even then the surgeon may still be in doubt. Since surgeons became aggressive in their attitude to the gall-bladder, many cases of obliteration or stricture of the hepatic or common duct have occurred as the result of surgical injury during cholecystectomy.

When the abdomen is opened, it is first necessary to make a careful examination to discover the exact nature of the obstruction and to determine whether or not it can be dealt with directly. For instance, a new growth of the ampulla or the pancreas may be removed (pp. 986, 987),† or an obliteration of the bile-duct treated by reconstruction of the duct When the obstruction is of such a nature that it cannot be removed, it may be treated by short-circuiting the area; anastomosing the gall-bladder to some part of the gastro-intestinal canal or uniting one of the ducts or, very rarely, a rawed surface of the liver to the intestine. Sometimes it may be expedient to establish external

* *Brit. Journ Surg.*, 1935, xxiii, No 90, p 293, *Journal Amer Med Assoc*, April 22, 1950, 1262–7.
† *See* Gordon-Taylor, *Brit Med. Journ*, 1942, ii, 119, where the whole question is reviewed.

drainage and to perform a short-circuiting operation as a secondary proceeding or to unite a resulting biliary fistula to stomach or small bowel.

CHOLECYSTENTEROSTOMY

Preparation.—All that has been said about the preparation of the jaundiced patient is especially important in these cases.

Technique.—The second part of the duodenum is the ideal site for the anastomosis, but it is not always possible to get the gall-bladder to lie in contact without tension. In these circumstances the anastomosis may be made to the stomach. Anastomosis between the gall-bladder and the stomach is reasonably safe and satisfactory; it is also technically easy and physiologically sound. In any case, the anastomosis should be made by direct incision and continuous suture.

It may first be necessary to draw off some of the contents of the gall-bladder, as otherwise it may be too tense to handle and the needle will puncture its lumen. In any event, very fine needles and suture material should be employed. If the bile is thick and tarry, it may not flow through the trocar, and the fundus will have to be incised for its evacuation. Incidentally, it may be noted that the chances of relief from the interference are slight when the contents of the viscus are thin, clear, and watery or mucoid. The actual union is made in the same way as any intestinal or gastro-intestinal anastomosis. Although it is not essential the operation is cleaner and more orderly if a light bowel clamp is applied to the fundus of the gall-bladder and to a portion of the viscus selected for the anastomosis The openings to be united should be at least an inch long. It is probably better to excise a piece of the gall-bladder wall about an inch in diameter; when this plan is adopted there seems to be less tendency to contraction of the anastomosis. The actual union is made with continuous catgut, the first layer passing through all the coats so as to be watertight and hæmostatic, the second layer uniting the peritoneum only. One or two additional Lembert sutures should be applied here and there, and any tags of omentum or neighbouring appendices epiploicæ tacked to the line of union. When the duodenum is selected for the anastomosis the incision in its wall should be transverse. If the stomach is to be used the anastomosis may be made wherever the gall-bladder lies most snugly against it, and this will usually be near the pylorus. The abdomen should be closed without drainage.

If these operations are going to be very difficult and involve much separation of the tissues, with consequent risk of hæmorrhage in jaundiced patients, they had better be carried out in two stages—first drainage, followed some weeks later by secondary anastomosis. For this latter purpose the abdomen is re-opened through the original incision and the gall-bladder is detached from the parietes. If the opening in the fundus is not large enough for the anastomosis it must be extended. The anastomosis is then made as already described. The results of this two-stage operation, both immediate and remote,

have been very satisfactory and the mortality has been about halved.* *If good bile drainage* does not become established after the first stage it is probably not worth while making the anastomosis unless as a means of getting rid of the external fistula. The method has the advantage that in cases of doubt it provides an opportunity for carrying out cholangiography for diagnosis.

When the gall-bladder is not present, or is shrivelled or inaccessible, the operation just described is not possible. The surgeon may then unite any part of the dilated ducts to the nearest and most accessible part of the bowel (*choledocho-enterostomy*) or stomach, great care being taken to avoid tension, and the anastomosis being protected by neighbouring fat. If the ducts are not available for the anastomosis, then the operation of *hepato-cholangio-enterostomy* may be carried out, but this is of very doubtful value.

CHOLEDOCHO-ENTEROSTOMY

The preparation of the patient and the preliminary steps of the operation are the same as for any common duct procedure. The common duct may be divided transversely and its open end implanted into an incision in the duodenum (Fig. 403) but as a rule it is much better to make a lateral implantation. When the common duct is much dilated, the operation is carried out exactly like cholecyst-enterostomy and there are no special difficulties As a rule, clamps cannot be applied either to the duct or the duodenum, but they are not essential If the duct is very distended or tense it may be aspirated as a first step Great care must be taken with hæmostasis. The surgeon must also take care not to narrow the anastomosis by too great finesse in burying the deep sutures. When the duct is only moderately dilated, the incision will have to be made oblique or nearly vertical to secure an opening of sufficient size It should be wide enough to admit the tip of the forefinger



Fig. 403 —Choledocho-enterostomy. First stage. (The opening in the bowel should be much larger)

Complications.—In some cases, though jaundice is relieved, distressing symptoms may follow. These take the form of rigors, fever, vomiting and often recurrence of jaundice, and are due to ascending cholangitis perhaps due to regurgitation of stomach or duodenal contents into the gall-bladder Fruit skins and other food débris have actually been found (J. Borrie†).

In an attempt to avoid these complications some surgeons make the anastomosis to a loop of jejunum with an entero-anastomosis

* Sir John Fraser, *Brit Journ Surg*, vol. xxvi (1938–39), 393.
† *Brit Journ Surg*, 1948–9, xxxvi, 326.

and one or two valves made by infolding the wall of the proximal loop (Fig. 411). It is thought that this exclusion renders the biliary tract less liable to infection from regurgitation of intestinal contents. If these complications do not yield to treatment it may be worth while re-opening the abdomen, for the anastomosis may be contracted, thus interfering with free biliary drainage, and can sometimes be re-made Should this not prove feasible a slice of the edge of the bile-logged liver may be excised and the resulting bare area be united to the duodenum or some other part of the small intestine—hepatico-duodeno-enterostomy. Of course this is only done in the expectation that the dilated radicles of the biliary tree may discharge their contents directly into the bowel. This plan is sometimes followed by slight amelioration for a short time, but as a rule no benefit follows and most surgeons who have tried it regard the operation as useless If stenosis at the site of union is not the explanation, Mallet Guy has suggested that the area should be excluded by dividing the stomach near the pylorus, closing both ends and making a gastro-enterostomy.

Results.—These depend on the condition demanding the interference. Short-circuiting in cancer of the pancreas or ducts is a most disappointing operation and carries a mortality of about 40 per cent It often fails to relieve itching and jaundice, and would not be worth while were it not that in a certain proportion of the cases the supposed cancer turns out to be the result of pancreatitis. When that is so the results are often very good, and this is what may be expected in any non-malignant condition. This operation has the unusual merit of revocability.

OPERATIONS FOR BILIARY FISTULA, FOR INJURIES TO THE DUCTS, AND FOR OBLITERATIONS

Reconstructive Surgery of the Biliary Ducts

Biliary fistulæ.—In this section only *external* biliary fistulæ are dealt with. Such fistulæ may give exit to bile, or only to mucus. In the former case all the bile secreted may escape in this way, or part may find its way into the intestine by the normal channels. The flow may be intermittent or continuous, and sometimes the fistula may heal for a time, only to break out again. The mucous fistula may behave in a similar way. In either case, gross infection may be superadded For successful treatment it is essential to have some idea of the cause of any particular fistula.

Spontaneous fistulæ.—These are due to suppuration in the gall bladder, with discharge of an abscess on to the surface. They are usually mucous fistulæ due to impaction of a calculus in the neck of the gall-bladder The external opening may be in almost any situation on the right side of the body, though usually it is about the umbilicus These cases may be looked upon as examples of the neglect of surgery, and are rapidly becoming extremely rare.

Post-operative biliary fistulæ, strictures or obliteration.—The great majority of these conditions met with at the present day are complications or sequelæ of operations for the relief of gall-stones, though they may, of course, occur after drainage of the biliary tract carried out for obstruction of uncertain origin, and they may occasionally follow accidental or war injuries. Overlooked calculi are the commonest single cause of persistent fistulæ following surgical intervention, but many cases follow surgical injuries of the ducts. The comparative frequency of strictures or obliterations of the common or hepatic ducts met with during the last few years, and the flood of literature dealing with their management, are a striking commentary on the dangers that may attend cholecystectomy. At the same time they are a great reproach to surgery.

Indications for surgical interference.—In many cases it is difficult to decide when a fistula may be said to be permanent, or to have reached a stage at which surgical interference is justified. When the biliary tract has been deliberately drained there is a wide variation in the quantity of the fluid discharged and in the time it may continue, although ultimately to be followed by recovery. Generally speaking, external bile-drainage seldom continues for longer than three weeks after removal of the tube, and if it does so, the probable further duration depends on the amount of bile reaching the intestine. If there is enough to colour the fæces, the patency and the continuity of the duct are demonstrated, and continued external drainage need not occasion alarm, for bile may be discharged to the surface for months, and yet healing and restoration to the normal channel may follow. If, on the other hand, bile is never found in the evacuations, or there is evidence of only slight intermittent discharge into the bowel, the fact suggests some condition which will require surgical intervention. In some cases the fistula closes intermittently, and if when it is closed, the patient is perfectly well and the evacuations are normal in colour, spontaneous cure may confidently be anticipated. On the other hand, if when the fistula closes the patient feels seedy, and little or no bile reaches the stools, and there is a tinge of jaundice, with perhaps slight pyrexia, some mechanical obstruction certainly exists. The question, however, is further complicated by the knowledge that this amount of obstruction may be due to an overlooked fragment of stone which may safely pass in the course of time, and this is suggested by repeated attacks of colic. In these circumstances it may be well to wait. When deepening jaundice follows the closure of a fistula, there can be no doubt that there is some mechanical obstruction which will require surgical intervention. The combination of persistent biliary fistula with jaundice can occur, though it is not easy to explain how it is produced. It is a good working rule to consider the necessity for interference if a fistula continues after three months. A pre-operative diagnosis of the cause of the fistula is very helpful, but it is often extremely difficult to make. The matter is complicated by the

fact that the primary operation has often been carried out elsewhere, and important information may not be obtainable. For these reasons every case must be considered as a problem which requires a review of the illness preceding the fistula, of the conditions found at the operation if ascertainable, and of the symptoms which have attended the fistula, as well as a careful investigation of the condition at the time of the contemplated interference. *The method of cholangiography (see p. 952) with lipiodol may furnish great help.* If a remaining calculus is the cause this may be dissolved by the instillation of ether. (Pribram, *see* p. 953.)

The operation which may be required.—When a fistula is due to fixation of the opened gall-bladder to the parietes and there is no obstruction in the ducts, it is sufficient to separate the viscus and to close it by suture, the abdominal wall also being repaired, or the gall-bladder may be removed. When overlooked calculi are the cause they must be dealt with according to the principles already laid down. Obliteration or stricture of the cystic duct always demands cholecystectomy. Strictures of the common duct may occasionally be *successfully treated by plastic operations or by divulsion.* Recent injuries to the great ducts may be dealt with by direct end-to-end suture. Old injuries and obliterations demand union of the gall-bladder to some part of the gastro-intestinal canal, but when that viscus has been removed end-to-end union, plastic restoration, or implantation of the proximal end of the duct into the duodenum are the methods available. Some few cases have been successfully treated by implanting the fistulous tract directly into the stomach or some part of the bowel.

Special preparation.—These patients are often in poor condition, are anæmic, and usually suffer in a marked degree from the special proclivity to hæmorrhage which attends jaundice. Some days should *therefore be spent in preparation on the general lines already indicated* on p. 910. Blood-transfusion may be of great value, and may give just that stimulus which will ensure a good result The discharging sinus should be carefully dressed with moist perchloride or other antiseptic gauze so that the surrounding skin may become charged with the chemical

General observations on the surgery of ducts.—*These structures* all contain a good deal of elastic tissue, and in consequence when partially divided they tend to gape, but if the division is complete the lumen immediately contracts and the ends separate widely, thus favouring subsequent occlusion. They are only very loosely connected to the tissues in which they lie, and these form a sort of a sheath in which they easily move. Their mucous membrane is fortunately possessed of great reparative power, and tends to grow longitudinally, and is capable of bridging a considerable gap or making up for a considerable deficiency, if there is the merest shred to guide it in the proper

direction. Ducts do not atrophy appreciably from disuse, though they readily contract and become obliterated as the result of infection, with its attendant inflammation and consequent development of scar tissue. In the repair of torn or divided ducts the most important point is to secure approximation of the ends; it is not necessary to obtain accurate apposition, but there must be alignment and there must be

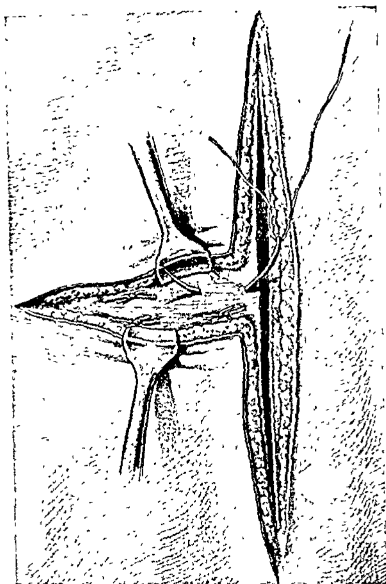


Fig. 404.—Method of preventing retraction of rectus by fixing it to its sheath with a few sutures preparatory to transverse division.
(Modified from Sir Henry Gray's figure in *Brit. Journ. Surg.*)

no tension. The sutured part should be wider, i.e. have a bigger lumen, than the normal duct. This is secured by enlarging the ducts to be sutured by making a small longitudinal slit in the ends (Fig. 405, p. 965.)

Technique.—These procedures may be among the most difficult

and anxious in surgery, and should only be attempted by those who are accustomed to operate on the liver and its ducts. Every accessory may be required, and the operations should only be undertaken in a properly equipped operating-theatre, where good daylight or bright artificial light is available, where ample assistance can be obtained, and where everything that can possibly be required is at hand. A mechanical table is almost essential so that the height can be easily adjusted to suit the type of subject, and in order that the reverse Trendelenburg position can be adopted and varied at will. A skilled anæsthetist and an experienced assistant, with whom the operator is accustomed to work, are indispensable. The incision will be determined partly by the operator's preference and partly by the circumstances of the case. For instance, if a previous operation has left the gall-bladder adherent to the posterior part of an oblique incision, it will usually be necessary to adopt the same type of incision, though it may be varied as to its exact situation and length. When the choice is entirely in the operator's hands a vertical incision through the inner third of the rectus, or nearer the middle line, carried right up to the costo-xiphoid angle, and extending down as far as the umbilicus or even lower, will best serve the purpose. If still more room is required, it may be obtained by cutting the rectus across either at the middle of the vertical incision (Fig. 404) or just above the umbilicus. Such an incision has the advantage that it will suffice even when the liver is considerably enlarged as indeed is often the case. In most cases a very thorough separation of adhesions is essential in order to reach the ducts, and it greatly helps the exposure of the parts to separate not only the gall-bladder but also the dome of the liver from the parietes. Whenever possible, adhesions should be divided between forceps, and the ends ligatured ; even the smallest bleeding-point must not be neglected. The surgeon should endeavour to determine the pathological condition present, and decide on the plan to be adopted as soon after the preliminary incision as possible. For instance, if the gall-bladder has already been removed and it is clear that anastomosis must be made between the proximal end of the divided common duct and the duodenum, as few adhesions should be separated as possible, since in these circumstances they form a useful bond between the duodenum and the liver, and serve to prevent the exposure of the low-resisting cellular tissue.

It may be necessary to restore the common bile-duct (*a*) immediately after its division, as when it is injured as the result of a crush, or during the course of an operation such as cholecystectomy, or (*b*) at some remoter period when the ends have become widely separated and cicatrized and are buried in massive adhesions. Fine 4/0 chromic catgut is the most suitable material for the sutures, for having served its purpose it is absorbed. Some surgeons insist that the finest silk is more suitable for the bile ducts. It is usually best to employ interrupted stitches because they can be more accurately placed and there is less risk of narrowing the union.

(*a*) RESTORATION OF COMMON DUCT BY APPROXIMATION OF THE ENDS

In *recent cases* the first step is to identify the ends. They will have been cared for in deliberate excisions, but in other cases will probably be widely separated. The separation is much exaggerated when the parts are exposed as for a common-duct operation. The use of the Robson position (loin support), traction on the gall-bladder and the displacement of the duodenum downwards all tend to increase the distance between the ends. The upper end will usually be identified by the flow of bile, but if this is not obvious, some bile may be "milked" down by the fingers. The lower end may have retracted behind the duodenum, but may usually be found by displacing the duodenum downwards. When the ends are found, the next step is to see if they can be approximated without tension. This can often be accomplished in a surprising way even over a gap of an inch and

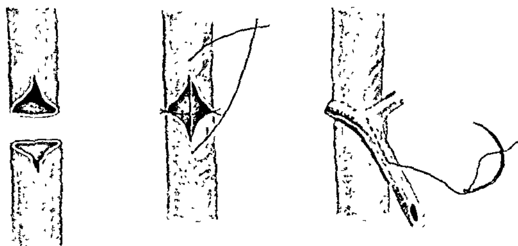


Fig. 405.—Repair of common duct. The ends have been enlarged. A split rubber tube is run down to the sutured area on one of the sutures.

a half. If there is difficulty, removal of the loin support and mobilization of the duodenum will accomplish a great deal. Sutures are then introduced. They should be of very fine chromicized catgut, and should be passed with a fine round needle in a holder. They can often be made to secure a good hold without actually perforating the lumen of the duct. Comparatively few sutures are required, and the knots must be outside the duct-wall. When possible, two sutures should be introduced into the tissues behind the duct and should be tied. These not only help to approximate the parts but also obliterate the dead space there. Three stay-sutures should then be introduced into the duct itself; the posterior part is first dealt with, and care must be taken that corresponding walls of the duct are approximated, *i e* to see that the ends are not rotated. Before putting in the anterior sutures the surgeon must satisfy himself that the lower part of the duct and the duodenal orifice are patent. If drainage is indicated,

it must be provided. This is best done by splitting up the antero-external wall of the upper end of the duct for $\frac{1}{3}$ in., and bringing a catheter out through this slit from the proximal end of the duct. Many surgeons recommend a T-shaped tube, which lies in the suture-line, *but this is wrong in principle, for ducts heal more kindly* and with less risk of stricture when there is no foreign body in contact with the suture-line and when the secretion is conducted to the surface from the proximal side. There is also a risk that the T-tube may tear away the union when it is removed, or that it may break, a portion



Fig. 406.—Repair of common bile-duct by direct suture.
(Modified from W. J Mayo's figure)
The T-tube is sometimes recommended for drainage, but is best omitted

being left behind in the duct. The region of the anastomosis is covered by the neighbouring tissues or by some tags of the gastro-hepatic omentum. When it is not considered necessary to drain the duct directly, a soft rubber tube must be brought from the region of the sutured duct to the surface, as in this method of direct suture there is almost invariably a little leakage. (Fig. 405) Any tube left in the duct should be removed in a week or ten days, after which the escape of bile will probably soon cease. Sometimes only a narrow bridge of one part of the duct remains. This should be most carefully preserved, *the duct being repaired over a rubber tube,* as mentioned in the next section

In *old cases* it may be extremely difficult to find and identify the ends but a great effort should be made to do so as end-to-end union gives by far the best permanent result.* Where there is a bile fistula the track will lead to the upper cut end of the duct. When the duct is obliterated, the part above the obstruction will be distended; but it is not readily seen, as it may be very near the liver, and in fact the experience of the Mayo Clinic has shown that it is usually almost flush with that viscus and buried in the midst of scar tissue. Of course, if still present, the gall-bladder is the guide to the duct, but if, as is usual, it has been excised, the gall-bladder notch guides the operator to the scar tissue in which the upper end of the duct is embedded. It may often be identified by introducing a hypodermic needle and withdrawing some fluid, but it must be remembered that the bile in these circumstances is nearly or quite colourless. Great care is

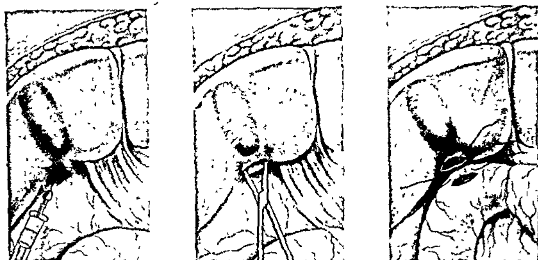


Fig. 407.—Diagrammatic representation of the steps necessary to identify and deal with the stump of the divided common duct.

necessary to avoid the portal vein, which may bulge into the space formerly occupied by the duct. When the upper end is identified it must be opened up to its fullest extent. As a rule this can easily be done by introducing the points of a pair of forceps along the track of the exploring needle and then separating the blades widely as they are withdrawn (Fig. 407.) Walters† has found with increasing frequency that by dissecting into the hilus a narrow rim, a mere fringe of duct can be found. By traction on this rim and careful dissection it is often possible to isolate enough to make the anastomosis. The lower end is not so difficult to find; it will not be distended, but on the other hand it will not be atrophied When there is great uncertainty, the duodenum may be opened and a probe passed up from the ampulla. If the upper end will not easily reach the lower, so that the two may be sutured together without tension, the difficulty may be overcome by

* Waltman Walters, *Lancet*, Aug 13, 1949 Frank Lahey personal communication, 1949
† Walters, *Lancet*, Aug 13, 1949

freely mobilizing the duodenum. This is done by incising the peritoneum as it leaves the second part of the duodenum for the posterior abdominal wall. A vertical incision about two inches long will usually allow the duodenum to be displaced inwards and upwards—the process can be assisted by blunt separation carried out by the finger tips in the retroperitoneal tissue. Unless the ends can be approximated fairly easily it is not worth while proceeding with an attempt to perform direct anastomosis, and the condition must either be dealt with by restoration, as described subsequently, or by hepatico-duodenostomy (page 970).

(*b*) RESTORATION WHEN THE ENDS CANNOT BE APPROXIMATED

This may have to be carried out immediately, as for instance when a large section of the duct has been removed in the excision of a growth or a stricture, or as a secondary operation when the ends have become widely retracted. In these circumstances the gap may be bridged by one of the following plans:

1. **Over a tube** (Sullivan).—Originally rubber tubes were employed but their use is now almost entirely superceded by those of one of the non-corrosible metals such as vitallium or by some plastic material. The tube to be employed is about the size of a No. 10 Jacques catheter, but whatever the material it must just comfortably fit the duct. If it is too tight it will exert injurious pressure on the walls of the duct and in this way defeat its own object by causing necrosis with loss of tissue and subsequent fistula, or healing with fibrosis with consequent stricture. The tube is introduced into the upper end of the common or the hepatic duct for about an inch, which will presumably be close to the union of the right and left hepatic ducts, and is fixed to the duct by a catgut suture or an encircling ligature. The tube then bridges the interval between the ends of the duct, and is passed through the lower end, until it can be felt projecting for about an inch into the duodenum. (Fig 408) Whenever possible, some part of the duct is brought together over the tube, in the hope of establishing continuity of the mucous membrane at some one point. The tissues round about are then drawn over the tube, and it is finally completely wrapped round by omentum, which is fixed to either end of the duct, to the duodenum, and to the tissues in the vicinity by a few points of suture. If the lower end of the duct is not available or the tube cannot be introduced, it should be passed directly into an oblique opening made into the duodenum, and the wall of the latter fixed to it by purse-string suture and then tucked in over it, as in the Witzel method of gastrostomy Mouat* found it more satisfactory to fix the tube into the duodenum as the first step. It is wise to provide for external drainage. The tube usually finds its way into the bowel but it has been vomited. The time taken for the tube to be voided has varied from

* *Lancet*, July 23, 1938, ii, 181

about three weeks to six months. Whatever the material employed the tubes are liable to become blocked and have to be removed through an independent incision in the duodenal wall. As long as the repaired duct is functioning it is not necessary to consider removal of the tube irrespective of the time it may have been *in situ*. Eventually the continuity of the duct is restored. The new duct will not be lined by mucous membrane, and stricture is likely to follow, and has done so in several recorded cases.

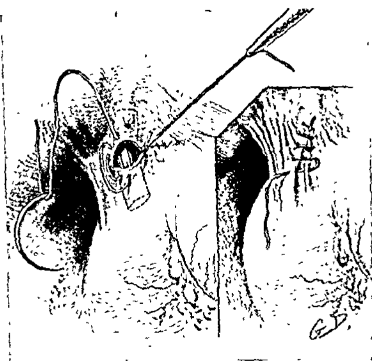


Fig. 408.—Reconstruction of common bile-duct over rubber tube. It is better to use interrupted sutures and much thinner catgut for the duct.
(*Modified from W. J. Mayo's figure*)

2. **By a flap cut from the duodenal wall.** (Walton)*.—It is claimed for this plan that a mucous-membrane-lined tube is provided which is therefore not likely to contract. The upper end of the common duct having been isolated, the superior border of the duodenum is drawn upon and is fixed to the structures about the hilum so as to diminish the gap as far as possible. The largest-sized rubber tube which it will admit is then passed into the upper end of the duct, and is fixed to it by suture. A flap is then cut from the upper surface of the duodenum and is sutured to the margin of the duct and around the tube, the lower end of which is introduced into the bowel. The union may wisely be supported by an omental graft. The method is well shown in Fig. 409. As a precautionary measure a soft tube is brought from the neighbourhood to the surface.

* A. J. Walton, *Brit. Journ. Surg.*, Oct 1921, ix, 169

3. **By direct union of the hepatic duct to the duodenum (hepatico-duodenostomy).**—This method is the only one available when the gap to be bridged is very extensive. It has certain advantages which lead the Mayos to look upon it as the method of choice,

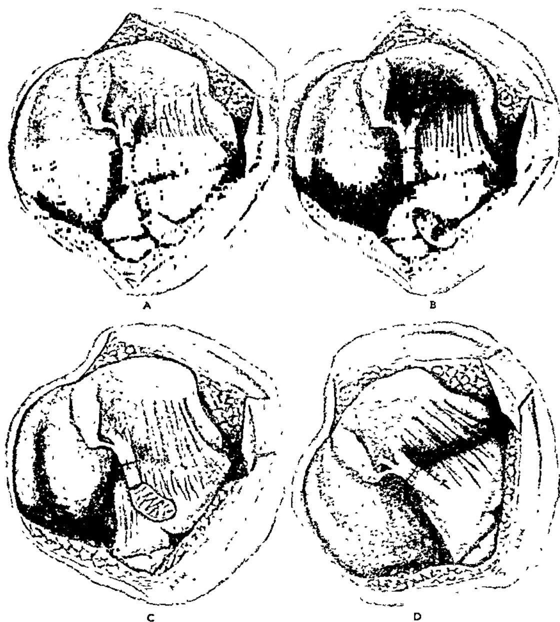


Fig 409 —Reconstruction of common bile-duct by Walton's method.
(Re-drawn from "Brit Journ Surg," October, 1931, by permission of Sir A J Walton)

A, Duct divided and open [illegible]
tube s[illegible]
latter c[illegible]

and with this view I certainly agree The first case operated upon by W. J Mayo was reported in 1905, and the patient was known to be alive and well fifteen years afterwards.

Technique.—The duodenum must be located, but fortunately the distal end of the common duct need not be identified. The proximal end of the hepatic duct must be found, and all that has been said in the previous section applies to this stage of the difficult operation. The stump of the duct is, as a rule, flush with the liver, and the best guide is the gall-bladder notch which leads down to a mass of tissue in which the duct will almost certainly be found. When identified it is freed as much as possible, but even so, only a very short piece will be available. The duodenum is drawn up to the mass of scar

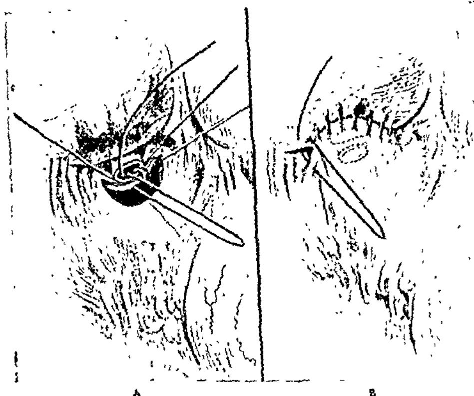


Fig. 410.—Technique of hepatico-duodenostomy.

A. Exposed end of the hepatic duct being sutured to a large open ... in the ...

(Re drawn from figure in "Ann. Surg," March, 1921, by permission of Donald C. Balfour, Mayo Clinic)

tissue round about the site of the duct, but it should not be separated posteriorly, as it is only *necessary to have* access to a small part of its anterior wall A few sutures should be inserted behind the site of the proposed anastomosis, to draw the bowel as near to the stump of the duct as possible and to diminish the risk of pull on the anastomosis. A slightly *curved flap* is then dissected out of the entire thickness of the duodenal wall, over an area which will leave an opening into the bowel about 2·5 cm. in diameter. It should be realized that there is always a *tendency* to contraction and that

the opening should be large enough to admit the forefinger. (Fig. 410, A.) The edge of the flap is sutured with catgut to the *posterior* and lateral walls of the hepatic duct, so that there is a muco-mucous union of the posterior and postero-lateral two-thirds of the duct. The free edge of the anterior margin of the opening in the duodenum is now sutured to the anterior edge of the stump of the duct and to the capsule of the liver or to the scar tissue just in front of the remainder of the hepatic duct, thus completely burying it, or, in other words, covering the opening in the duodenum with part of Glisson's capsule and neighbouring scar tissue. Next, a much wider area of the duodenum is drawn up and sutured to the liver to cover the anastomosis and to take off all tension. Neighbouring omental tissues are then packed round the anastomosis and fixed with a point or two of suture. Though leakage is not invariable, a soft rubber drain should always be brought from the neighbourhood, and if there is no discharge it may be left until the first dressing at the end of a week, or otherwise until discharge nearly ceases. Balfour of the Mayo Clinic reports* that the results, both immediate and remote, are very satisfactory, and the writer, with subsequent experience, can fully endorse this statement. So far as Balfour knows, bile has always been properly delivered into the duodenum, and few cases of subsequent stricture have occurred. But though this method has proved very encouraging there are cases in which cholangitis of varying severity occurs and vitiates the result. When this complication comes on early the symptoms may subside and the patient be apparently well, but later developments and findings may show stricture formation as a result. In this way a vicious circle is set up for drainage may be seriously impeded by the narrowing. On the other hand the cholangitis may be virulent in type and may be associated with multiple abscesses and soon prove fatal. In the hope of obviating this complication Warren Cole† and A. Allen‡ have recommended division of the jejunum

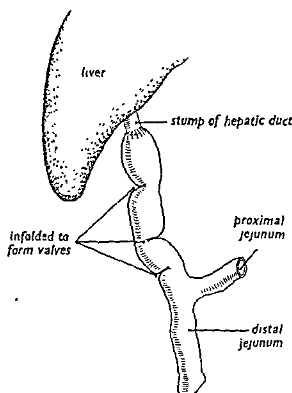


Fig. 411.—Hepatico-duodenostomy. The bowel is infolded as a safeguard against reflux of intestinal contents.

* *Ann. Surg.*, March, 1921, lxxiii, 343.
† Warren Cole, *Advances in Surgery*, New York, 1949, vol 1.
‡ *Annals of Surg.*, 1945, 121-412.

about two feet below its origin. The proximal end of the common hepatic duct is implanted into the open end of the divided jejunum over a vitallium tube or a catheter as a protection against stricture at the union. The proximal jejunum is then joined end-to-side into the jejunum about two feet lower-down. As a further safeguard against reflux of intestinal contents through the anastomosis and so into the biliary tree, a series of baffles is made by infolding the bowel wall in one or two places (Fig. 411). This plan is still on trial, and it remains to be seen how far continued observation will show it to be effective.

Much ingenuity has been displayed by surgeons* in devising other methods of carrying out the operation but all prove to have their drawbacks.

Divulsion of the strictured area of the common duct with forceps.—For those cases in which the stricture is in the pancreatic portion of the duct, the result of ulceration, it has been found satisfactory to open the supraduodenal portion of the common duct and pass a pair of dilating forceps through the strictured area until it is completely divulsed. Strictures in this vicinity are usually in the nature of a diaphragm, and will often tear like paper when forceps are passed through them into the duodenum. After divulsion a piece of rubber tube may be placed through the strictured part of the duct, and left projecting for half an inch into the duodenum. It should be fixed by a single stitch to the wall of the duct and will in due course be safely discharged into the bowel. In any event the neighbourhood of the incision in the duct should be drained for a time.

In the more difficult cases it will occasionally be found necessary to open the duodenum and expose the papilla before undertaking divulsion of the stricture. In any event the method is only suitable for simple annular stenosis.

Transplantation of external biliary fistula into the duodenum.—This operation, which was first carried out as long ago as 1905, must be looked upon as an intervention of dire necessity and not of choice. It may be expedient when the multiplicity and density of adhesions renders exposure of the stump of the hepatic duct impossible or when an attempt at direct anastomosis has failed, with a resultant fistula. When confronted with what looks like inevitable failure the surgeon may be wise to endeavour deliberately to make an external bile fistula which can later be implanted into the bowel.

Technique.—The first step is to pass a catheter into the fistula as far as it will travel. The instrument must not fit too tightly or it may cause necrosis of the wall of the track. The abdomen is then opened by an incision including the fistula about its centre. The fistulous track is then dissected free of the parietal tissues and down towards the liver It should be "cored" out with a considerable amount of surrounding tissue to ensure its nutrition. The nearest

* McCurrich, *B J.S.*, 1944, xxxi, 304.

accessible portion of the duodenum is then found, so that the mobilized tract can be laid against it without tension. An opening which will just admit the track is made into the viscus and the fistula is drawn into it by an attached suture in the same way as the ureter is drawn into the bowel in transplantation. The incision in the duodenum must then be closed around the transplant. *It is most important that the infolding sutures should not constrict the implant.* Further protection is given by surrounding the union with a piece of omentum tacked here and there by a catgut stitch.

Choice of operation.—When an injury to the common duct is recognized at the time it occurs, it will usually be possible to effect repair by direct suture, and this should be the surgeon's aim. If for any reason the ends of the duct cannot be approximated and the gall-bladder remains, it should be united to the duodenum or stomach, the proximal end of the duct being ligatured. In old patients the same ideal of end-to-end union should be the aim. When the gall-bladder has been removed the choice will generally lie between reconstruction of *the duct or direct anastomosis of the hepatic duct to the duodenum.* Occasionally a limited stricture of an accessible part of the common duct will lend itself to plastic repair—longitudinal division with suture in the opposite direction. Similarly, a localized area of stenosis might be excised and continuity restored by direct end-to-end suture. Stenosis at the lowest part of the common duct can often be successfully treated by divulsion. In these matters the experience of the staff of the Mayo and the Lahey Clinics is unrivalled, and they regard end-to-end restoration as by far the best method* though recognizing that hepatico-duodenostomy has to be the operation of choice in many cases Though intubation will help to bridge a large gap this method has many disadvantages and is falling into disfavour.

COMPLICATIONS AND SEQUELÆ

1 Hæmorrhage and escape of bile into the peritoneum just after operation have already been dealt with at page 954. In jaundiced cases there may also be late bleeding coming on after several days and sometimes with serious consequences It may be into the peritoneum or into the wound and large quantities of blood may slowly collect.

2. Some slight external escape of bile is almost to be expected but such leakage may develop into a *biliary fistula.* When this is associated with jaundice it is of grave significance and suggests progressive hepatitis In the absence of jaundice spontaneous healing may occur even after some weeks and there should be no hasty interference.

3. *Duodenal fistula* if it occurs in the first few days will quite likely close spontaneously but when it appears from about the tenth day onwards the prognosis is grave.

4. *Cholangitis* is not unusual. One type comes on within a few days of operation and is not usually severe though there may be chills,

* Waltman Walters, *Lancet*, Aug 13, 1949, and Lahey, 1949, Personal communication

tenderness and toxæmia. But this sequel may occur after months or even years and may be very pronounced and associated with multiple liver abscesses proving fatal either rapidly or after a slow remittent course.

5. *Jaundice* is often very slow to recover even when the presence of bile in the evacuations proves that the repair or anastomosis is effective.

6. There may also be indications of *hepatitis* slow to recover or progressive.

7. Patients who do very well sometimes develop attacks or colic after months or even years of good health. These attacks may be due to secondary *stricture* at the site of the repair or may be caused by the formation of *gall-stones* in the duct. These conditions may coexist.

Results.—The surgical procedures which have just been described are very serious undertakings, and the mortality following them is necessarily high, and not always truly represented by the published figures. Repeated operations have sometimes been necessary, and small fistulæ have remained in spite of the most adroit surgical proceedings In general terms it is fair to say that about one-third of the cases die of the immediate effect of the accident, another third from the operative intervention necessary for repair; and that among the survivors there are many late deaths. Even when the operation has been successful, in the sense that a fistula has been closed or an obliterated duct restored, complete cure has often been marred by some degree of persistent narrowing or recurrent sepsis in the ducts. In some cases calculi have formed after these operations and have been successfully removed. Nevertheless, several cases have been recorded which have remained well over periods of from five to twenty years, and this is the only criterion of success.*

Choledochectomy

This operation may be required in order to deal with a primary malignant growth of the extrahepatic bile-ducts, or an extension of malignant disease from the gall-bladder or from the stomach or colon, or for resection of a stricture or obliteration following simple ulceration or some type of injury. It may also be part of an operation for the removal of a tumour of the ampulla of Vater. Primary malignant growths are usually small and well localized, and may easily be overlooked or mistaken for gall-stones. A certain type of growth may remain local for a considerable time, and does not lead to early involvement of the lymph nodes or secondary deposits. This especially applies to tumours of the ampulla

Preparation.—The general preparation recommended for jaundiced patients must be carried out with special care, and steps must be

* The following were the results in 12 personal cases [illegible]
case alive and well 5 years later [illegible]

taken to combat the anæmia; blood-transfusion may be exceedingly valuable.

Two-stage operations.—The operation of choledochectomy may be tedious and difficult, and may involve much separation of adhesions, as well as the division of many small vessels which are difficult to catch and tie. Prolonged operation and minor traumatism conduce to bleeding, and make the worst possible combination in jaundiced patients. The surgeon must therefore consider the advisability of operating in two stages. The first stage would consist of an exploration to determine the exact condition present and the feasibility of a subsequent radical operation. This preliminary interference must be conducted with the utmost gentleness and the greatest regard for hæmorrhage, and with all the precautions that are proper to operations in jaundiced patients. Having determined that radical operation holds out good prospect, the surgeon provides external bile drainage, via the gall-bladder, whenever possible, though it may have to be directly from a dilated duct. If the conditions are such that prolongation of life and addition to comfort are problematical, as in some of the cancer cases, it will be wise to be content with a palliative anastomosis of the gall-bladder or a dilated duct to the gastro-intestinal tract, and thus to conclude the operation in one stage. With non-malignant conditions a later interference after preliminary drainage may make all the difference, as the risk is greatly lessened when jaundice and its risk of attendant cholæmia have disappeared.

Technique.—The incision must be one of those already described for the deeper ducts, as adequate exposure is essential. The steps are as follows :—

1. Thorough exploration with special regard to secondary deposits in cases of growth.
2. Isolation of the duct above and below the spot where it is to be divided.
3. Division of the duct and decision as to the method of repair.
4. Repair or substitution.
5. Toilet of the operation area.

Great care must be taken at this stage not only to exclude the presence of secondary deposits but to see that there is no such infiltration of surrounding parts, e.g. the portal vein, as might prove an obstacle to successful removal at a later stage of the operation. With recent advances in the technique of vascular surgery, there need be no hesitation in removing a portion of the portal vein, as this vessel may safely be diminished by suture, and it seems probable that even resection of a part of the vein with end-to-end suture need not prove an insuperable bar. The actual division of the duct must be strictly transverse, and steps must, of course, be taken to prevent the ends retracting until a decision has been made as to their disposal. If the ducts are dilated to twice or thrice their normal size and they can be approximated without tension, end-to-end union, as described in the previous section,

may safely be employed. At this stage great help may be secured by mobilization of the duodenum. When the divided ducts are not much larger than normal, or there is difficulty in approximation, the surgeon must decide whether to implant the hepatic duct into the duodenum or carry out one of the reconstruction methods already described. In this decision he must be guided by his own experience and the conditions present in the particular case. There is not yet enough accumulated experience to enable anyone to say definitely which method ought to be employed as between reconstruction of the bile-duct or hepatico-duodenostomy, though the latter method has often been very successful.

Operation for Cancer of the Ampulla of Vater

This condition can often be dealt with by the transduodenal route. A probable diagnosis having been made as the result of the examination, the duodenum is opened by a longitudinal incision over the site of the mass felt in its lumen. The latter can then, as a rule, easily be drawn forward for examination. If the diagnosis is confirmed and previous examination has shown that there are no secondary deposits in the liver and no enlarged lymph nodes, the excision may be completed. The base of the tumour, with half an inch of healthy mucous membrane round about, is encircled by an incision which goes completely through the bowel-wall, opening up the cellular tissue between the duodenum and the pancreas. By making gentle traction and using the dissecting-forceps, the tumour with the duct is isolated, and this separation must be continued until the common duct is seen free half an inch above the tumour. The pancreatic duct must also be identified. (Fig. 412.) Both ducts are now caught in forceps (not crushed) so that they cannot retract, and are cleanly divided. The cut ends are then sewn together with a stitch, and their open mouths are conjointly fixed by a few points of suture to the wall of the duodenum, in such a way that mucous membrane is continuous with mucous membrane. It is often impossible to identify the pancreatic duct, in which case it may safely be left to look after itself, care being taken not to obliterate by suture the area in which it may be expected to lie. If the opening in the inner wall of the duodenum is too large, either the upper or the lower part is diminished by suture. If there is a free escape of bile into the lumen of the bowel, nothing further is necessary, but if there is any doubt the gall-bladder should be independently drained, or a tube may be passed up the common duct and left projecting for half an inch or so into the duodenum, where it is fixed by a stitch to its wall. The duodenal incision is now sutured in the transverse axis so as to increase rather than diminish its lumen. If jaundice is present the operation may be done in two stages. Whipple and his co-workers* have devised a very radical method which, they hope, will bring more cases within the range of operability and secure better late results. The first stage

* *Annals of Surg.*, Oct 1935, cii, 763. Brunschwig, *Journ. Amer. Med. Assoc.*, Jan 3, 1948, cxxxvi, 29-35.

comprises posterior gastro-enterostomy, ligation and division of the common bile-duct and cholecystogastrostomy. At the second intervention, three or four weeks later, the descending part of the duodenum is resected, with the growth and a V-shaped portion of the pancreas. The ends of the duodenum are closed, and the pancreas is repaired by suture, the duct being ligatured and allowed to retract.* This method will require extended trial to show whether it gives better long-term results.

Results.—In new growths the operative mortality has been between 35 and 50 per cent., but it may be expected to improve with more efficient preparation of jaundiced cases. Recurrence is almost to be

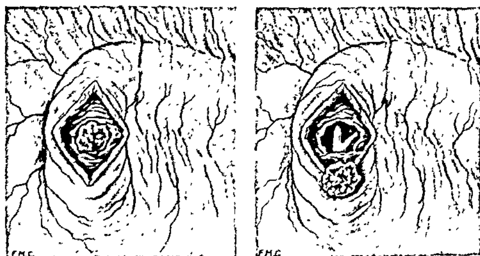


Fig. 412.—Diagrammatic representation of removal of new growth of ampulla of Vater by trans-duodenal route.

expected, as even in the most favourable cases it may not be possible to excise enough healthy tissue with the growth. Some few cases on record were alive and well up to fifteen years after operation (Upcott).

Congenital Cysts of the Common Bile-duct

Simple drainage or marsupialization has usually been followed by exhaustion, severe infection, hæmorrhage and death. Excision is seldom feasible, and when attempted has invariably proved fatal. The best results have followed anastomosis of the cyst to the stomach or duodenum (Morley). In very ill patients simple drainage may be useful, but only in the expectation of carrying the patient on to such time as anastomosis to some part of the alimentary canal can be more safely undertaken

Technique.—One of the vertical incisions will probably give the best exposure. If the cyst is very large and tense it should be rendered flaccid by aspiration. The part of the cyst which lies most comfortably

* Gordon-Taylor, *Brit Med Journ* 1942, ii, 119

in contact with the stomach or duodenum should be selected for the anastomosis. The union should be made as described under *cholecystenterostomy* (p. 958). Great care must be taken to secure accurate hæmostasis. If the contents of the cystic dilation are grossly infected, temporary external drainage should also be provided. A small drain (size No. 12 rubber catheter) should be inserted and securely fixed by a purse-string or other type of suture. Tags of neighbouring loose tissue or a portion of omentum should be fixed around the tube to guard against leakage. To ensure that the drainage opening *will*

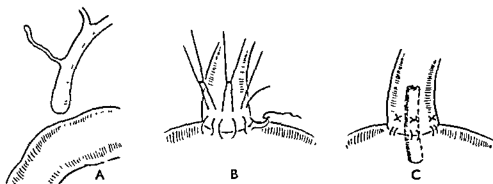


Fig. 413.—Cholecystenterostomy for atresia of the bile-ducts. A, Before operation. B, Implantation of the common bile-duct. C, Temporary supporting tube in position.

close spontaneously after the removal of the tube, the cyst must not be attached to the parietes. Such a drain can probably be safely removed about the tenth day.

Congenital Atresia of the Bile-ducts

When this condition is suspected exploration should be carried out when the child is about four months old. If the gall-bladder is present, cholecystenterostomy is indicated. In the absence of this viscus the blind end of the common duct must be implanted into the duodenum with or without the temporary support of a tube. Through and through sutures of silkworm or silk should be used for the parietal wound.

Results.—Ladd of Boston* stated that 37 per cent. of the cases presented possibilities of successful surgical intervention, and of those operated upon 60 per cent. recovered. Patients were alive and in good health from six months to twelve years after operation.

* *Annals of Surg*, Oct, 1935, cii, 742, also Ladd & Gross, "Abdominal Surgery of Infancy and Childhood," London 1941

CHAPTER XVII

OPERATIONS FOR DISEASE OF THE PANCREAS

By G. GREY TURNER

Anatomical and physiological observations.—A thorough knowledge of the *surgical anatomy* of the pancreas is of the greatest importance, as its close relations with many important organs in the upper abdomen lead to complications in diagnosis and prognosis, and add very much to the difficulties attending surgical intervention. The pancreas lies transversely across the abdomen at the level of the first and second lumbar vertebræ, and as it is entirely behind the peritoneum, it is covered by the stomach and the lesser sac, the posterior layer of which lies in front of it. It rests on the aorta, having the cœliac axis immediately above it and the superior mesenteric artery and vein below and behind. Its *tail* touches the spleen, a point to remember in doing splenectomy; the *body* is in such close relation to the stomach that it is often invaded in the saddle ulcer of that organ; and the *head* is in close contact with the pylorus and the first and second parts of the duodenum, which forms three-fourths of a circle above, to the right, and below. But perhaps the most important relation is to the bile-passages. The common bile-duct, in its course to its termination in the duodenum, passes behind the head of the pancreas, and in two cases out of three is actually surrounded in this part of its course by pancreatic tissue.

The pancreas has two ducts—one, the duct of Wirsung, which in all but a small percentage of cases (10 per cent.) joins the common-bile-duct just before its duodenal opening at the ampulla of Vater, and the smaller, the duct of Santorini, which does not always function. It follows, then, that, while on the one hand diseases of the head of the pancreas may interfere with the permeability of the common bile-duct, on the other hand gall-stones or infections of the common bile-duct may have a direct influence on the main duct of the pancreas. In practice it is found that cancer of the head of the pancreas, and even chronic inflammatory hyperplasia, are often the cause of jaundice. The commonest cause of pancreatitis is infection associated with gall-stones in the bile-passages. Whether this is brought about by direct infection along the ducts, or secondarily through the lymphatics, is undecided, and is not a matter of great importance from the operative standpoint. The anatomical fact that the common bile-duct and the duct of Wirsung unite to open into the duodenum by a common orifice is generally accepted as the governing factor in the causation of acute hæmorrhagic pancreatitis.

Physiology.—The pancreas is a racemose gland comparable with the

salivary glands, with the modification that between the secreting acini lie the islets of Langerhans which elaborate insulin.

The external secretion is strongly alkaline, has a specific gravity of from 1012 to 1014, and a composition of 98·5 per cent. water and 1·5 per cent. solids. The secretion is under both nervous and hormonal control. The parasympathetic vagus fibres when stimulated cause a flow of viscid juice rich in ferments, while secretin, elaborated when hydrochloric acid from the stomach comes in contact with duodenal mucosa, causes a copious secretion of juice of low specific gravity and poor in ferments.

It is probable that the pancreatic ferments (trypsinogen, amylase, lipase, maltase and very small amounts of rennin) are elaborated in a relatively inert form and are only activated by enterokinase, a product of the duodenal mucosa. This is certainly true for trypsinogen. When the juice is activated by contact with the intestinal secretion, or with bile, it becomes highly destructive to the tissues other than the intestinal mucous membrane. It is this property that accounts for fat necrosis, hæmorrhages and destruction of cellular tissue in pancreatic disease or injury. The same effect may be produced on the pancreatic tissue when there is retrojection of bile along its main duct, and this is probably the commonest cause of pancreatitis.

Insulin is produced by the islets of Langerhans and its main function is to regulate the metabolism of the carbohydrates. When this function is at fault diabetes mellitus results. The islets are scattered throughout the gland but are most abundant in the tail. It is said that a normal gland contains more than one thousand times more insulin-producing tissue than is necessary for the normal needs of the body. Total pancreatectomy in the experimental animal is followed by the development of diabetes and wasting which is not entirely prevented by the administration of insulin. Raw pancreas given by the mouth is of value though not entirely protective. A diet rich in lipoids, particularly lecithin, helps to maintain health in a depancreatized animal. Large portions of the human pancreas or the whole organ are now not infrequently surgically removed without serious disturbance, as the resulting diabetes can be readily controlled by diet and insulin.* The stools are usually frequent and fatty but nutrition is generally maintained and patients are able to lead a more or less normal life. Diabetes only rarely results from such destruction of the gland as may follow inflammations. Even temporary glycosuria is infrequent in pancreatitis.

Indications.—Operations on the pancreas are performed for tumours (simple and malignant), cysts and pseudocysts, stone in the pancreatic duct, acute and subacute infections and injuries. The latter are dealt with at p 982 Chronic infections and jaundice due to irremovable cancer of the pancreas are treated indirectly by operations on the bile-passages (p. 957).

* Priestley *et al*, *Annals of Surgery*, Aug, 1949, cxxx, 211–217.

General operative considerations.—The following special points must be borne in mind when it is necessary to operate on the pancreas. Patients whose condition demands such interference are often exceedingly ill, particularly cases of acute inflammation or where malignant disease is the indication. These cases are rarely of an emergency nature and should not be operated upon without careful preparation. Those general measures employed before undertaking any major operation must be intelligently carried out. When there is jaundice, even of slight degree, it is wise to give a course of vitamin K, and the resources of chemotherapy and blood transfusion must be utilized. Patients who do not respond to such measures must be considered as the worst risks and should be subjected to only minimal interference in the first instance. The pancreas can be exposed either through the gastro-hepatic omentum, the gastro-colic omentum or the mesocolon (Fig. 418, p. 996), and the route chosen will depend on any bulging which may be present into one or other of these situations If there is nothing to give a lead, then it is probably best to use the route through the gastro-colic omentum. In the more chronic cases there are often strong adhesions to the surrounding parts and especially the posterior surface of the stomach, and sometimes inflammatory exudates find their way into this viscus. The operator must take care not to anticipate nature in this respect, for a hole torn into the back of the stomach in these circumstances may be very difficult to close. The vascularity of the pancreas is much increased in the presence of inflammation and, quite apart from large trunks, the smaller vessels are capable of giving rise to serious bleeding. The substance of the gland is always friable, especially in the presence of disease. It should *be torn as little as possible, for pancreatic secretion very readily* escapes and this may have most serious consequences For this reason a drain should always be brought from the neighbourhood, although it need not actually be in contact with the pancreas. Any raw area on the latter should be covered whenever possible, either by drawing the neighbouring tissue over it and fixing it with sutures or by using omentum for the purpose. Catgut should not be used as it is said to be digested by the pancreatic secretions with harmful effects. Fine silk or linen or nylon is recommended. In any event there must be maximum hæmostasis.

TUMOURS

Pancreatic tumours, if innocent, are cystadenomata or fibromata, which are rare. Adenomata of the islets of Langerhans have, of recent years, been recognized as one of the causes of hypoglycæmia, and several examples of their successful removal are on record. Primary malignant tumours may be sarcomata or carcinomata, the latter are being recognized and dealt with by operation with increasing frequency.

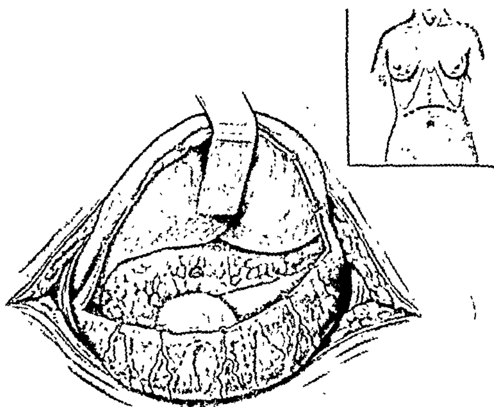
Non-malignant Tumours

In actual practice, opportunities for dealing with such tumours are rare. Encapsulated growths may be successfully enucleated and

those near the tail can be removed together with that part of the organ. In all cases raw areas must be drawn together by sutures or covered by omentum, and drainage must always be provided.

The Surgical Treatment of Hypoglycæmia

Technique of removal of islet-cell tumours.—In the management of these cases there must be the closest co-operation between physician and surgeon. *Where so many important chemical examinations are involved* it is for the physician to select the appropriate time for the operation and to supervise the necessary pre-operative and



post-operative régime Complete relaxation of the abdominal wall is essential It is suggested* that a wide transverse incision about 2 in. above the umbilicus and dividing both recti should be employed (Fig. 414) It certainly gives a very good exposure, but an ample mid-line or para-median incision with good retraction is also adequate. The gland is approached through the gastro-colic omentum, which is divided sufficiently to give unimpeded access. The tumours may occur in any part of the gland though perhaps with greater frequency

* Whipple and Frantz, *Annals of Surg.*, June, 1935, ci, 1299.

in the body and tail. They may present as purplish nodules slightly raised above the surface of the gland and 1 to 2 cm. in diameter. If the suspected tumour is not obvious, the pancreas should be carefully palpated by running the fingers along its surface, when the adenoma may be detected like a buried pea. But this is not enough to exclude a deeply situated tumour which may only be detected by palpating the gland between the finger and thumb (James H. Saint). It may be necessary to make the more thorough exploration described by Ian Aird,* who found that in 23 per cent. of recorded cases an existing tumour had not been detected at operation. The tumour may be situated in the head and on the posterior or deep surface, which should be examined before concluding that no adenoma is present. To expose the back of the gland the peritoneum must be incised along its lower border. These tumours may also be multiple and, when one has been found, a careful search should be made for others.

The line of cleavage between the adenoma and the gland can be demonstrated with a blunt dissector, with which instrument the tumour is usually easily enucleated. Vessels that bleed must be caught and carefully tied with the finest catgut or silk. If there is oozing from the bed from which the tumour has been enucleated, or if the pancreatic substance has been torn, the sides of the bed should be drawn together with one or two fine stitches. It is probably safer to bring a small rubber drain ($\frac{3}{16}$in. in diameter) from near the tumour site up through the parietal incision. Should there be no leakage no harm will ensue and the tube can be removed at the end of a week. In some cases there is quite a copious discharge of pancreatic juice and the drain proves a necessary safeguard, for when it has been omitted pancreatic fluid has sometimes accumulated in the lesser sac, causing alarming symptoms of peritoneal irritation and necessitating secondary drainage. The gap in the gastro-colic omentum should be drawn together with a few stitches and the parietes carefully repaired by layer suture. The rectus sheath should be drawn together with interrupted sutures, but it is not necessary to put stitches in the muscle itself.

If an adenoma cannot be found where the clinical story and complete investigation strongly point to hyperinsulinism it is recommended that $\frac{2}{3}$ of the pancreas, that is to say, the tail and the body excluding the head, should be removed.

Partial pancreatectomy. Technique.—The stomach must be held well up and the colon down, and it will still further help if the loin is elevated, as in gall-bladder operations. The peritoneum is incised along the lower border of the gland. The tail is first separated from its connections and is gently drawn downwards. The branches from the splenic artery passing into the upper border of the gland will be exposed, and must be carefully caught, ligatured and divided. If the splenic artery and its veins lie very closely along the upper border of the

* Ian Aird, Proceedings 13th Congress International Society of Surgery, New Orleans, 1949.

pancreas it will be wiser to put a temporary ligature around them at an early stage or deliberately to ligature and divide them. It will often facilitate the operation to remove the spleen, but this is not necessary simply because the artery has been tied, for its other vascular connections are sufficient to prevent necrosis. Once the pancreas has been released from its vessels it can be readily separated from the tissues in which it lies and can be drawn towards the surface. It is not necessary to clamp the gland at the site of the proposed division, in fact it is better not to. The division should be made deliberately so that any vessels, or even the duct, may be seen and caught before being severed, otherwise these structures retract and are often difficult to catch. It is better, though not essential, to divide the gland in a

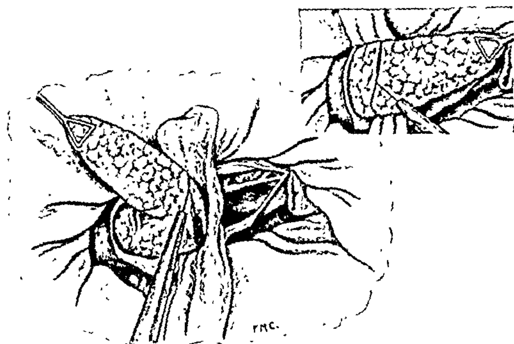


Fig. 415.—Partial pancreatectomy. (*After Mallet-Guy, redrawn.*)

"V" shape so that the flaps may be sutured together to cover the raw surface (Fig. 415.) It is sometimes recommended that the gland should be cut across with the diathermy knife or seared with the cautery. The stur [illegible] uried, and a rubber drain shot [illegible] ie parietal incision While ca [illegible] there has been a free escape of pancreatic secretion, sometimes continuing for weeks. Among the published cases the mortality has been very low, probably due to the fact that the operation has only been undertaken by experienced surgeons. But such an operation must always be potentially serious (a mortality of 16 per cent. in 150 operations, Ian Aird *loc. cit*) and should never be lightly undertaken. The obesity which is a frequent accompaniment of hypoglycæmia has often proved a serious embarrassment to the surgeon. The results in both types of

intervention have been most encouraging. An extensive literature has already accumulated about this subject.*

Malignant Tumours

In suspected malignant disease of the pancreas, when there are no unequivocal signs of dissemination, an abdominal operation may be justifiable—

(*a*) to establish the diagnosis;
(*b*) to consider removal of the growth even if that means partial or total pancreatectomy;
(*c*) to relieve jaundice and itching by anastomosis of the gall-bladder to one of the hollow viscera.

Malignant tumours are nearly always *carcinomata and as they so* frequently arise in the head of the gland and give rise to obstructive jaundice they have acquired an evil reputation. The condition usually takes the form of a diffuse infiltration and it is only very rarely that a more defined and localized growth is found. In the diffuse type it may be very difficult to decide on the nature of the enlargement at operation. On rare occasions tumours of the islets of Langerhans removed for hypoglycæmia have, on histological examination, proved to be malignant. Apart from this accidental finding, there are cases on record where well-defined malignant tumours nearly as large as a fist have been encountered. When such tumours arise in the tail or even in the body *they may lend themselves to extirpation together* with that part of the pancreas in which they are situated. Their removal must follow the lines of partial removal of the gland which has just been briefly described. As in all operations for abdominal cancer, the surgeon must first be satisfied *that there is no dissemination to* the liver, that glandular invasion is not extensive, and that local extension of the growth, especially posteriorly, does not render the attempt at removal unwarrantable.

Partial removal technique.—It is essential that exposure should be adequate, and the surgeon must not hesitate to make a sufficiently long mid-line incision and also, if necessary, to acquire still more room by cutting across one or other rectus muscle, usually the left. The transverse incision described in the previous section may be entirely satisfactory As a rule, the intra-abdominal approach will be through the gastro-colic omentum, but the growth of the tumour upwards and forwards may dictate the gastro-hepatic omentum as the better avenue. At an early stage the splenic artery and vein should be exposed, ligatured and divided, after which there need be little fear of uncontrollable *hæmorrhage, though all vessels seen must* be carefully caught

* [illegible] and F. C. Mann (*Quart. Journ.* [illegible] T [illegible] 46, [illegible] most helpful

The last paper gives a follow up report on a case of total pancreatectomy for *hyperinsulinism five and a half* years after operation the patient continuing in good health

before being severed. When the tumour is in the extremity of the tail, removal of the spleen will be almost a necessity, but even with a tumour farther removed splenectomy will often facilitate the intervention. When the pancreas with the tumour has been completely freed from its surrounding connections, it should be lifted well forwards into the wound so that the body of the gland may be clearly seen before being divided. It is not necessary nor is it wise to put a clamp across the gland, which should be divided section by section. Vessels are caught and tied, also the duct if seen, sutures being introduced and some tied before the division is complete. The sutures should be of silk, linen or nylon. Needless to say, hæmostatis must be accurate and drainage must always be provided.

Operation for removal of the head of the pancreas and for total removal of the gland. Pancreatoduodenectomy.—This operation has become a recognized procedure for excision of all but the very limited carcinomas of the ampulla of Vater, for similar growths in the lower part of the common bile duct, for carcinoma of the head of the pancreas and for most malignant tumours of the duodenum. If, after thorough preliminary examination, the surgeon decides that extirpation of the pancreas is feasible, the necessary intervention should be carried out either at one sitting or in stages. As a rule the staged operation is in two sittings but in very ill patients with deep jaundice it may be wise to make simple external drainage of the gall-bladder a first step. If after two or three weeks both the jaundice and the state of the patient are sufficiently improved the operation of excision can be carried out either as a final intervention or in the two further stages as described.

Whether carried out in one intervention or as a staged operation the scope is the same and necessitates.

1. A free exposure of the upper abdomen through a long median or para-median incision.
2. A careful exploration to confirm the diagnosis, to exclude metastasis and to establish the possibility of excision.
3 The union of the outlet of the biliary system to a new site, either in the stomach or intestine.
4. The provision of a new outlet from the stomach usually by gastro-enterostomy.
5 The excision of the greater part of the duodenum either with the head of the pancreas or the whole of that gland, *en bloc*.
6. Closure of the ends of stomach and duodenum If part of the pancreas has been left its cut surface is usually implanted into the bowel.

The illustrations indicate some of the methods by which these ends are attained.

The steps of the operation, whether carried out in one or more stages, are much as follows: The first stage consists of gastro-enterostomy, ligature of the common bile-duct and either cholecysto-gastrostomy or implantation of the duct itself into the bowel. The second is the removal

been fixed in the parietal incision and if the surgeon is in doubt as to the proper course this is quite a good plan. The best technique for union of the bile duct and the pancreas to the stomach or bowel is not quite settled. The bile duct may be introduced for about half an inch into the lumen of the intestine where it is left free, its wall being fixed at a few points by interrupted sutures to the edge of the incision in the bowel. The union is then slightly inverted—intussuscepted—and so fixed by a series of Lambert sutures. Neighbouring tags or a piece of omentum may be applied rather like a muffler to re-enforce the junction.

Where the growth cannot be removed, biliary obstruction and itching, due to the resulting jaundice, may be relieved by cholecysto-gastrostomy. In inoperable cases Sampson Handley implanted radon seeds into the mass with some success.

The immediate after-treatment does not differ from that required for any other abdominal operation of magnitude. When a large part of the pancreas or the whole gland has been removed, metabolism will be disturbed and dietetic regulation and the proper use of insulin will become essential It is in these circumstances that the co-operation of a physician can be so very helpful, and should therefore be available.

Results.—Of the older records in Finney's 17 cases, 9 recovered, and 8, all malignant cases died.* He considered that the prognosis depends upon the situation of the growth, being more favourable in tumours in the tail of the pancreas than in those nearer the head, while if they are pedunculated the prognosis is still better which of course remains true to-day. Gordon-Taylor's patient was alive and well for eleven years after removal of a massive carcinoma of the body of the gland. Recurrence then took place, leading to death just over thirteen years after operation.† In Sherren's case,‡ a sarcoma of the head of the pancreas, the patient was in good health eighteen months after operation. The later figures deal with the results of the more extensive pancreatic excisions which involve duodenectomy and are among the later developments of aggressive abdominal surgery. The figures available at present reflect the work of the formative period and include much pioneer effort which will help to build up the established technique of the future. So far the best results, both immediate and remote, have been in malignant disease of the ampulla of Vater where pancreatico-duodenectomy has been carried out. The immediate mortality has been about 15 per cent. and a fair proportion of cases are alive and well for over three years. So far as the complete operation for growths in the pancreas is concerned, the mortality has been about 50 per cent. and of course every surgeon knows that many fatal cases are not recorded. Whipple states that in the hands of those with special experience the mortality has much improved during the last three or four years and has been reduced to about 10 per cent. (7·7 per cent.

* *Trans Amer Surg Assoc*, 1910, xxviii, 315
† *Ann Surg.*, July, 1934, c, 206, also *Brit Med Journ*, 1942, ii, 119
‡ *Lancet*, 1911, i, 1491.

Brunschwig*). Similarly the long-term results show encouragement and there are a few patients alive and well after three or four years. Unfortunately for statistics in some of these there was doubt about the nature of the original disease.†

CYSTS

Cysts of the pancreas may be divided into *true cysts* (retention, cystic adenoma, hydatid) and *pseudo-cysts*, which are either inflammatory effusions into the lesser sac or collections in the peri-pancreatic tissues.

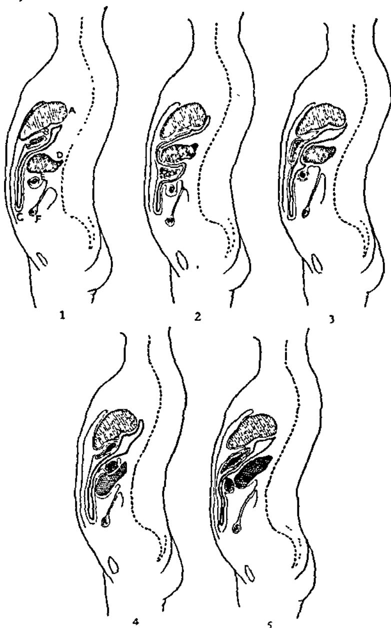


Fig. 417.—Diagram of pancreatic cysts, showing different presentations.
1, Gastro colic, 2, gastro-hepatic, 3, *retrogastric*; 4, subcolic; 5, retrocolic.
A, Liver, B, stomach, C, omentum; D, pancreatic cyst; E, transverse colon; F, small intestine

* *Cancer*, vol II, No. 5, 1949

† Richard Cattell *et al*, *Annals of Surgery*, 129 (840–849), June, 1949

These pseudo-cysts sometimes attain a considerable size, and have given rise to many mistaken diagnoses.

Cysts usually present between the stomach and the transverse colon, being covered by the gastro-colic omentum. (Fig. 417.) Occasionally they displace the stomach downwards, and present between the stomach and the liver through the gastro-hepatic omentum. If they arise from the tail of the pancreas they may grow into the mesocolon, either displacing the colon downwards or lying behind it. Albert and Page report a case in which the cyst emerged through the foramen of Winslow.

As a rule it is only the smaller pancreatic cysts that can be completely removed, but the question of operability cannot be determined until the surgeon has the opportunity of making a complete exploration with the abdomen opened. It is not entirely a question of size, but of the fixity of the cyst to the surrounding parts and especially the nature *of its attachment to the pancreas. There can be no doubt that in the* majority of cases drainage is all that is necessary, and it is certainly much safer than total removal. Nevertheless, when there are few adhesions or perhaps none at all, and the surgeon can explore the site of attachment at an early stage of the operation, there are some cases in which the cyst may be safely enucleated from the pancreas and there are others situated near the tail of the gland in which the cyst may be removed together with a part of the gland. In a series of 46 cases reported (to April, 1930) from the Mayo Clinic, 7 were enucleated or excised and 33 drained, and 6 were partially excised and drained. If the cyst cannot be completely removed, it is often possible to excise a considerable portion, but in doing this the surgeon must be sure that he leaves enough cyst wall to attach to the parietes for drainage. In all cases where drainage is to be carried out, the interior of the cyst should be gently explored, for sometimes masses of débris may be removed and will facilitate recovery. But manipulations inside the *cyst must be gentle*, as *otherwise serious hæmorrhage may* be set up and may be difficult to control. If the cavity is very large or there is hæmorrhage, it may be wise to pack lightly with gauze. In any case a large tube will have to be left *in situ*. For the pseudo-cysts drainage is all that is necessary.

Technique.—The abdomen is opened by a supra-umbilical median incision. In most cases it will be found best to expose the cyst by dividing the layers of the gastro-colic omentum. The general peritoneal cavity must be shut off with flat swabs, as the contents of the cyst might irritate the peritoneum, or at least the fat in the abdominal wall, *in the event of an accidental rupture. The cyst having* been exposed, its relations and attachments must be investigated. There are four main methods of treatment available—complete enucleation, partial removal with drainage, drainage after suturing the cyst-wall to the parietes (marsupialization) and drainage into one of the hollow viscera. There is no doubt that enucleation is the most satisfactory, as it generally allows immediate closure of the abdomen.

Treatment by drainage may be prolonged. Unfortunately there are very few cases in which removal is feasible. If enucleation be decided upon, it is better to separate the attachments without evacuating the cyst-contents, but great care is necessary to avoid rupture. If the cyst-wall is thin, and therefore likely to give way, and there seems a good prospect of enucleation, the cyst should first be emptied through a cannula before the deep separation is done. The cyst is enucleated by blunt dissection; often considerable hæmorrhage is encountered. The principal danger is injury to the superior mesenteric artery, an accident which is almost certain to prove fatal. Injury to the splenic artery or to the arteries of the stomach is less serious, as these organs have additional supplies.

After removal of the cyst, the area must be examined in a good light, any bleeding-points controlled, and the pancreas sutured if it is lacerated. It may be necessary to use absorbable cellulose gauze packing to control oozing from the cyst-bed, but this should be avoided whenever possible as it encourages subsequent fistula. If unabsorbable gauze must be used, it should be wrapped in rubber tissue and a tube inserted in addition, to provide drainage after the gauze is removed.

If enucleation or removal with a portion of the pancreas is considered inadvisable, the cyst-wall is brought up to the abdominal incision and sutured to the parietal peritoneum. If it will not reach up to the parietes, the cyst should be emptied through a cannula, when it will be found easier to bring the wall forward. An incision is made into the cyst, either at once or subsequently (Gussenbauer's two-stage operation), and a large drainage-tube inserted. In pseudocysts it is only necessary to establish external drainage. An anterior incision over the most prominent part of the swelling is usually employed, but when the cavity is very large, and especially when it extends towards the left, a second independent drainage opening may greatly facilitate recovery. The latter should be made in the left subcostal space near the border of the erector spinæ. As the fluid from these cysts, at least from the true cysts, may irritate or even digest the skin, a protective dressing of white of egg is a wise precaution.

After-treatment.—The tube can usually be removed in two or three weeks, by which time the discharge will probably be much lessened. Thereafter it may quickly cease, or may persist for so long as to be very troublesome. In that case special consideration must be given to diminishing secretion and inducing the track to close. A strict diabetic diet has been found effective in reducing the amount of discharge, and the addition of much fat to the diet has the same effect. Wohlgemuth advises bicarbonate of soda in large doses. Irritation of the skin may be mitigated by drying it and painting with white of egg or milk or 2 per cent. hydrochloric acid.

Internal drainage.—Cysts that cannot be completely removed or brought to the surface for marsupialization, or in which it is desired to

avoid this plan, may be opened and united to the stomach or the upper intestine as a means of internal drainage. This method, which was successfully employed by the writer many years ago, has recently been advised and advocated by many surgeons.*

Before the actual anastomosis the cyst must be emptied or decompressed and care must be taken to see that it can be readily approximated to the intestine or stomach without tension and without risk of obstruction whether by angulation or torsion of the bowel. The anastomosis is made by direct suture in two main layers. In addition wide surfaces of the peritoneum round the union must be brought together. The opening must be of adequate size as some contraction is likely to occur. After suturing is complete it should admit the thumb. To avoid infection of the cavity by stomach or intestinal contents free use must be made of the antibiotics

Results.—Cases treated by drainage may be expected to make a good immediate recovery, with a mortality of about 2 per cent., but ultimate recovery is often slow, and there is a residue of patients with persistent fistulæ, and a few develop diabetes.

Complete extirpation can be performed in only very few cases, and carries a mortality of about 10 per cent.

INFECTIONS

Inflammations of the pancreas, excluding the rare cases due to such disorders as mumps, typhoid fever, tuberculosis, and syphilis, result from coincident infections of the bile-passages. It follows that, while in some cases of acute and subacute pancreatitis a direct operation may be done on the gland, it is often necessary to combine this with some procedure designed to counteract the infectivity of the bile. In chronic pancreatitis operative treatment is mainly directed to the gall-bladder and biliary ducts.

Although it is customary to speak of acute pancreatitis as hæmorrhagic, gangrenous or suppurative, these are not clear-cut clinical types and their main features may overlap to a considerable extent. As met with in practice, the cases usually range themselves in one or other of three groups: (1) the very acute fulminating varieties, which may turn out to be hæmorrhagic or gangrenous. Death often occurs within 48 hours and autopsy may disclose diffuse hæmorrhagic infarction or infective necrosis of the greater part of the gland. Obviously there is little that can be done in such very acute conditions, and it is doubtful if opening the abdomen adds to the chance of recovery. If a case which begins as a major abdominal catastrophe does happen to show signs of recovery, there may be a stage at which drainage of the gall-bladder or an incision into the extra-peritoneal tissues may help. (2) The next group is an acute variety but of moderate severity in which spontaneous recovery may occur either with or without the formation of localized abscesses. (3) In a third group, in which pancreatitis is found usually unexpectedly on opening the abdomen, the

* Rapant *et al*, *Jour Internat de Chirurgie*, Jan, Feb, 1950, Tome X, No 1

symptoms are those of an accompanying acute gall-bladder infection, often with suppurative cholecystitis.

Surgeons disagree on the place of operative interference in acute pancreatitis but the present tendency is in favour of not operating. When it is thought best to wait, the case should be managed as one of peritonitis, the resources of modern therapy being used to the full. In the opinion of the writer it is wiser to operate if diagnosis is uncertain for, leaking ulcers, acute biliary infections and even high intestinal obstructions have all been mistaken for pancreatitis and drainage of the biliary system is a valuable method of influencing the course of the disease. Mistakes in diagnosis, however, are less liable to occur now that the value of the concentration of serum amylase is realized and is being more widely used to confirm the clinical features of the suspected case. If the case is not seen until the acute symptoms have settled down and the patient is improving in *every* respect, operation is not indicated. Sometimes improvement occurs up to a point and is then arrested or is followed by pyrexia and other signs of recurrent inflammatory trouble with evidence of pancreatic insufficiency. In these circumstances a lump may be detected about the situation of the gland. This usually means that there is some necrosis with abscess formation. Sometimes these abscesses find their way into the stomach or duodenum, but if this does not occur they should be explored. In these circumstances the wisest course is to be content to open and establish drainage, sloughs can be more safely removed after the drainage track has been shut off.

Epitome of surgical treatment.—Most benefit follows free external bile drainage, and many cases recover following this procedure. When the gall-bladder cannot be easily reached for this purpose, it may be possible to open the common duct. The gall-bladder must never be removed, as it may be invaluable at a later stage for cholecystenterostomy. Incision of the substance of the pancreas itself is of doubtful value, but should it be considered advisable, a blunt dissector should be employed for the purpose, owing to the risk of severe hæmorrhage. If there is much effusion in the flanks, and evidence of retroperitoneal involvement, as shown by surface discoloration (Grey Turner's sign), separate incisions must be made in either loin to open up the retroperitoneal space for drainage. When there is a definite localized mass the surgeon may find a considerable retroperitoneal collection, which may be drained from the front. When the case is of longer duration and the symptoms indicate sloughing of a considerable part of the gland, the sloughs must be sought and removed. During convalescence the surgeon must be on the watch for signs of pancreatic insufficiency.

Technique.—The abdomen is opened in the middle line above the umbilicus or through a vertical rectus incision. The peritoneum nearly always contains fluid, which may be clear, straw-coloured, blood stained, or slightly turbid. The diagnosis is confirmed by the presence of fat necrosis, which is often the first abnormality recognized. The

biliary tract is then examined, the gall-bladder and common bile-duct being palpated for stones. In most cases a cholecystostomy is all that should be done. The patients are nearly always far too ill for measures requiring much manipulation, and unless stones in the common duct are easily accessible they should be left for a future intervention. The one essential *is to establish external biliary drainage.*

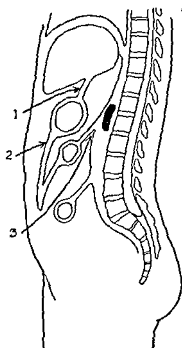


Fig. 418.—Lines of approach to the pancreas.

If it is considered necessary to expose the pancreas there are three lines of approach: (1) through the gastro-hepatic omentum; (2) through the gastro-colic omentum, and (3) through the transverse mesocolon. (Fig. 418.) Of these, the last, owing to risk of injuring the middle colic artery in swollen tissues, is not to be recommended. The approach through the gastro-colic omentum is the better of the other two. *The pancreas is exposed through* the lesser sac, after shutting off the general cavity of the peritoneum with moistened gauze swabs. *A certain amount* of blood-stained exudate is usually found around the gland. Punctures are made into the pancreas with a blunt instrument, and the organ is drained by tube or gauze tamponade.

There has been some difference of opinion on the advisability of attempting to drain the pancreas directly in the acute stage, before necrosis or pus-formation. Probably it is more a question of the relief of tension *by incising the coverings of the gland.*

The general peritoneal cavity need not be drained unless the fluid is obviously infected. Nevertheless, when there is a great deal of fluid which is flaky and perhaps offensive, *a tube from the pelvis through* an independent opening above the pubes may be a comfort both to patient and surgeon

If the pancreatic inflammation goes on to pus-formation, an abscess will form immediately around the pancreas, or it may pass towards the left lumbar region, or upwards to the left subphrenic space. If the pus cannot safely be reached from the original incision, separate drainage must be provided in the flank or subcostal region. (Fig 419)

Complications and sequelæ.—After the immediate danger of shock is passed, sepsis and hæmorrhage are the chief complications. With *sloughing of the pancreas* and with abscess, hæmorrhage is a serious and not unusual feature in the course of conv[illegible] The large arterial branches along the upper border of the [illegible] y derived from the splenic artery, are [illegible] *the source.* [illegible] mesenteric

veins may also become thrombosed, with fatal results. Large portions of the gland may necrose and be discharged as sloughs; sometimes only the head of the gland remains. In these cases, and even when there is much less destruction, pancreatic insufficiency becomes a serious menace. Continued slight vomiting is always a very suggestive symptom and, later, wasting, air-hunger and cyanosis are pathognomonic. To anticipate and correct this condition, care must be taken with feeding, and the secretion of the gland must be stimulated by the

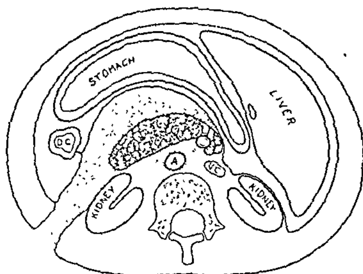


Fig. 419 —Drainage of pancreas through incision in left flank.
(After A. Dickson Wright, modified.)

exhibition of weak acids, while an attempt should be made to supply the deficient ferments by giving extracts of the gland by mouth. Estimation of the serum amylase and lipase is a guide to the extent and progress of the deficiency. In the later stages, persistent fistula or diabetes may occur. The treatment of fistula is discussed on p. 1000.

Relapses after operations for acute pancreatitis.—The majority of cases that survive operations for acute pancreatitis appear to be completely cured. Early recurrence may follow insufficiently prolonged drainage, but the condition may return after months or years. Recurrences are usually much less severe than the primary condition and normally recover without operation. A proportion develop chronic pancreatitis or diabetes, so that the prognosis after operation must be guarded. Recurring attacks of pain are probably due to overlooked gall-stones or to concomitant duodenal ulcer. Sometimes a cyst develops as a late sequel.

Results.—The mortality in cases operated upon during the acute phase may be expected to be about 20 per cent. When intervention is delayed, the mortality among those who survive and require operation is about 15 per cent. Writing in 1948, Whipple, who favours the conservative management, stated that in 46 cases treated in the previous

5 years the mortality was only 15 per cent. whereas in two previous similar periods when early operation was the rule, it had been 34 per cent.

CHRONIC PANCREATITIS

It may be agreed that, excluding cases due to certain specific infections, to pancreatic lithiasis, or to direct extension from ulcer of the stomach or duodenum, chronic pancreatitis results from some pre-existing and coincident infection of the gall-bladder or bile-ducts. It follows that, in order to obtain a cure, treatment must be directed to remedying the biliary infection. This is effected by removal of the cause, such as gall-stones, and by biliary drainage (for two to three months as a minimum). The simplest method is by cholecystostomy, but if the common bile-duct becomes occluded, a more or less permanent fistula may result, which is not only a great inconvenience but also deprives the patient of the digestive value of the bile. To overcome the difficulty, Winiwarter, in 1880, did the first anastomosis of the gall-bladder to the intestine, and at the present day this is the accepted treatment in cases of well-established non-malignant pancreatitis affecting the head of the organ. Four sites have been used for the anastomosis—(1) the stomach. (2) the duodenum, (3) the jejunum, (4) the colon. Anastomosis with the colon may be dismissed as inadvisable, if any of the other three courses is available, for the contents of the large bowel have a much higher degree of infectivity than the other parts of the alimentary canal. Cholecysto-gastrostomy is usually easy, and the introduction of bile into the stomach does not appear to cause inconvenience. Cholecysto-duodenostomy would seem to be the ideal procedure, as the bile enters the intestinal tract approximately at the spot where it should enter. It is not a very difficult operation, if the duodenum can be brought well forward. In some cases it may be necessary to adopt Kocher's method of mobilizing the duodenum, which consists in making a vertical incision in the peritoneal reflection just to the outer side of the duodenum and raising it forwards by blunt dissection with the fingers. In cholecysto-jejunostomy a point in the jejunum some 14 in. from the duodeno-jejunal flexure is chosen, and a loop brought across the abdomen below the omentum and upwards in front of the hepatic flexure of the colon. Anastomosis is easy, but to prevent delay in the passage of the intestinal contents, and also to lessen the risk of infection, it has been suggested that the operation should be supplemented by an entero-anastomosis between the afferent and efferent limbs of the loop. Details of these operations will be found on p. 958, but it may be said here that, of the four methods, anastomosis between gall-bladder and stomach is generally adopted and is as satisfactory as the other types If the patient is very ill or when there is jaundice or many adhesions the anastomosis may be made in two stages. As a first stage, external drainage of the gall-bladder is secured and, if the improvement in the condition justified further intervention, the gall-bladder is later

separated from the parietes and united to stomach or duodenum. The primary mortality has been much reduced by this plan.

In certain cases the gall-bladder may not be available—e.g. where it has been removed at an earlier operation. There are then two alternatives: (1) to anastomose the common bile-duct to the duodenum (choledocho-enterostomy), or (2) to arrange for prolonged drainage of the common bile-duct (choledochostomy).

Mallet-Guy states that the maximum amount of change in chronic pancreatitis is limited to the tail of the gland and for that reason recommends hemipancreatectomy. He has reported four cases in which the results were satisfactory. The technique is that described in connection with the treatment of hypoglycæmia (p. 984). The difficulty of clearing the splenic vessels is emphasized. Drainage is always employed, and discharge of secretion may continue for some weeks. Cases in which pain is the principal symptom may be much relieved by sympathectomy.

Results.—Cholecystenterostomy for chronic interstitial pancreatitis carries an immediate mortality of about 10 per cent. The subsequent health of the patient largely depends on the amount of damage sustained by the gland as the result of the inflammatory process.

Pancreatic Lithiasis

This condition is rare but with improvements in radiological technique and more attention to obscure cases more examples are coming to be recognized.* It occurs more often in men than in women. The calculi are usually multiple and vary from mere sand to the size of a walnut. They are not facetted and are usually light in colour. Though often found near the head of the gland, they may be scattered throughout its substance. There is often fibrosis, either of the whole gland or in the vicinity of the calculus, and this may make it difficult to detect the stones by palpation at laparotomy. About half the cases are complicated by diabetes. In the cases recorded where operation has been carried out the calculi have generally been situated in the head of the gland and have been removed by the transduodenal route exposing the ampulla of Vater through an incision in the second part of the duodenum. The opening of the ampulla is slit up, and the stones are removed from the duct of Wirsung with fine forceps or a scoop. In other cases a direct incision has been made into the gland and the calculus removed. When this has to be done provision for drainage by tube should be provided from the site. In most cases there is associated disease of the biliary tract in the form of calculi either with or without infection. For this reason a careful examination of the gall-bladder and ducts must always be made and any pathological condition appropriately dealt with. In such cases drainage of the biliary system is indicated.

* Court & Matheson, *Gastro-enterology*, vol. x, No 5, 1948.

The Pancreas and Gastrectomy

The pancreas often forms the base of an eroding gastric ulcer, and a crater may be left exposed when the stomach is separated from the gland in the course of gastrectomy. It is not necessary to excise such craters, but they should be wiped dry and dusted with sulphanilamide or lightly seared over with the cautery or swabbed with phenol.

Excision of a superficial portion of the gland may be necessary in the operation of gastrectomy for cancer. The wound so made should be drawn together by sutures or should be covered by adjoining tissue or omentum, and a track to the surface provided by a rubber drain. Gauze must not be left in contact with the gland, unless for the purpose of staunching otherwise uncontrollable oozing, for when removed it is apt to tear the surface and to encourage the escape of pancreatic secretion.

Encouraged by improvements in anæsthesia and the methods of preparation and care of patients, both during and after operations, surgeons are becoming much more aggressive in the management of stomach cancer.* In many cases the pancreas in whole or in part or the peritoneum overlying it, together with the whole stomach and the spleen, have been excised at one sitting with encouraging results. Such interventions require painstaking care on the part of the surgeon and his team and often occupy several hours. The mortality has been about 15 per cent. and recovered cases have obtained considerable palliation for some months.

Pancreatic Fistula

This condition may result from direct laceration, whether from injuries like gunshot wounds or such trauma as is necessarily inflicted during the course of the operative removal of tumours. It may also follow the drainage of cysts or inflammatory collections about the gland. Since the escaping juice is not activated by enterokinase it does not digest the tissues though it usually produces very troublesome irritation of the surrounding skin. When infected with pyogenic organisms it may cause severe general symptoms. After trauma the discharge may be expected to cease in three or four weeks as the healing process proceeds, but in pathological states it may persist for months or years. Generally speaking, little can be done to deal directly with the cause except in those cases which follow pancreatitis, when the removal of a slough may do much to bring the trouble to an end. The best line of treatment is continuous suction, which may be carried out by a water-pump of the Sprengel variety or an electrically-driven pump. The orifice of the fistula may be covered by a special cap, or a catheter may be introduced to which the suction apparatus is attached. In either case it is essential that the suction should not be too powerful or pain or hæmorrhage may result. When the discharge

* N C Tanner: Proceedings Roy Soc, of Medicine, vol xlii, No 9, Surgery Alex Brunschwig Cancer, *vol i, No 3, Sept, 1949*

appreciably diminishes the suction may be interrupted for some hours at a time, or for a day or two, when healing may follow.

Should the fistula become chronic in spite of treatment the outlook is not bright; its management will depend upon the underlying condition. If the operation has been for a cystic condition (true cyst) it probably means that this has not contracted and remains as a cavity of considerable size. In these circumstances the remains of the cyst may be anastomosed to the stomach or the upper intestine, whichever is more conveniently situated for the purpose. If, on the other hand, there is no cavity but merely a track, this may be dissected out from the parietes and implanted into the stomach or intestine in much the same way as is sometimes employed for chronic biliary fistula.

In the surgery of the pancreas the physiology of the gland and the metabolic disturbances that may follow its disorders play a most important part. For management to be successful the co-operation of an interested physician is well-nigh essential.

CHAPTER XVIII

OPERATIONS ON THE SPLEEN

By G. GREY TURNER

Anatomical and physiological observations.—This organ lies on the left side, hidden by the 9th, 10th and 11th ribs and with its long axis in the line of the tenth. It must be remembered that the lower part of the pleural cavity, and to a varying extent the lung, are interposed between the spleen and the surface of the body. Its protected situation means that, if palpable below the costal margin, it is probably pathologically enlarged. It is important to remember how closely the cardiac end of the stomach nestles into the hollow in front of the hilum and the way in which the tail of the pancreas abuts on the inner surface of its lower pole. Both these organs have been injured during the operation of splenectomy, and they must be identified in order to be avoided. The close relationship of the outer surface of the spleen to the under aspect of the diaphragm makes it apt to adhere to that structure. Relative to the size of the organ, the splenic vessels are very large, and in pathological states they may become enormous. The veins always appear to be unusually friable. The principal vessels lie in the lieno-renal ligament which connects the organ to the anterior surface of the left kidney, while the gastrosplenic omentum carries smaller branches of the splenic vessels—the vasa brevia—which pass to the cardiac end of the stomach (Fig. 425, p. 1012).

Accessory spleens are quite common and may be multiple. They are seldom larger than hazel nuts and usually lie between the layers of the neighbouring mesenteries On very rare occasions accessory spleens have attained such a size as to produce symptoms and justify removal. Splenunculi often enlarge after removal of the parent organ.

The size of the spleen, its sheltered position, its special structure and vascular arrangements and the variations in size which occur during normal health all suggest that the organ subserves some important function. Nevertheless, the continued observation of those in whom the normal spleen has been removed for injury go to show that at least the organ is not indispensable in the economy of the body.

In adult life it has to do with the destruction of red blood-cells, probably those that are worn out, with the disposal of particulate matter and with the metabolism of iron. It seems also to be a container for a reserve of blood, and in some obscure way appears connected with the blood platelets. It probably plays the part of a link in a physiological chain but it is not an indispensable one. Many spleenless people are perfectly well, and appear to be admirably adapted to their everyday environment, even when disturbed by physiological conditions such as pregnancy or by intercurrent disease.

Operative interference for injuries and diseases of the spleen is almost limited to removal.

Splenectomy for injury.—The spleen may be injured by stab wounds, firearms, explosions, blows, falls, crushes and sometimes exertion. Any disease of the spleen renders it more liable to the effects of trauma even when slight. In civil practice crushes such as are likely in motor car and railway accidents are the commonest cause. Subcapsular tears may give rise to late hæmorrhage some few days after the injury. In all forms of injury hæmorrhage is the main cause of death and, as the structure of the spleen makes suture almost impossible, splenectomy is the operation of choice except in some stab-wounds, in which it may be justifiable to attempt conservative surgery. Even in civil life and in the very best circumstances of early and efficient surgical treatment, the mortality is high. In warfare, complications are often present, especially wounds of the stomach or intestines, and these materially increase the death rate (p. 1015).

Splenectomy for disease. *Splenic anæmia.*—In this disease, characterized by an enlarged spleen, leucopenic anæmia, and spontaneous hæmorrhages, especially hæmatemesis, splenectomy has sometimes proved of value. Perisplenitis with numerous strong adhesions is a marked feature of this disease. It is generally held that there is some relation between the platelet count and the prognosis in splenectomy for this condition. When the count is high (250,000 to 400,000 per c.mm. is normal range) there is more risk of post-operative thrombosis in the splenic and portal veins.

Banti's disease.—This is probably only a later stage of splenic anæmia in which the liver is grossly cirrhotic (hob-nailed). The results of splenectomy have sometimes been encouraging. In the later stages, when ascites has supervened, the operation has been less successful, but if combined with omentopexy it may confer great benefit over a longer period.

Acholuric or hæmolytic jaundice.—Considering what is known of the functions of the spleen, splenectomy should have great value in diseases characterized by increased blood destruction and, in hæmolytic jaundice, both congenital and acquired, many successful splenectomies have been recorded The operation has a comparatively low mortality, and is followed by rapid disappearance of jaundice, with decrease of the anæmia, though the tendency to hæmolysis persists. It is most important not to operate during the crises which are characteristic of this disease. Pigmented gall-stones are often present and should be removed either at the time of the splenectomy or subsequently. It is also essential that spleniculi should be sought for and extirpated as their subsequent hypertrophy may account for recurrences.

Purpura hæmorrhagica.—The thrombocytopenic type of purpura is now recognized as one of the indications for splenectomy in which the results have, on the whole, been very satisfactory. It is essential that the operation should not be carried out during an acute phase. Blood

transfusion should always be done once or twice before the operation and the platelet count should be watched.

Hypersplenism occurs in other diseases such as Felty's Syndrome characterized by a rare but distinctive triad of arthritis of rheumatoid type, splenomegaly and leucopenia. Corneal ulceration and ulcers on the legs may also be present. Improvement has been recorded following splenectomy.*

Malaria.—The enlarged spleen has been removed on many occasions. Chronic malarial enlargement was one of the earliest conditions for which splenectomy was performed. When the bulk of such a spleen renders it an inconvenience and a danger, because of the liability to rupture from slight trauma, splenectomy may be considered. In the absence of adhesions the operation is reasonably safe; otherwise, the inevitable hæmorrhage makes it exceedingly dangerous.

Egyptian splenomegaly.—The ætiology of this condition is doubtful, but usually regarded as due to schistosomiasis. Many cases are treated by splenectomy with remarkable immediate success and sometimes lasting benefit. The organ may be enormous and its removal then affords great relief.

Abscesses and *cysts* whether simple or hydatid may require splenectomy rather than drainage or local incision. On rare occasions *new growths* like carcinoma or sarcoma of the organ may be found sufficiently localized for removal by splenectomy.

Wandering spleen cannot be cured by splenopexy with any certainty, and removal is necessary. When complicated by *torsion* of the pedicle the operation becomes an emergency. Whenever possible, a careful blood examination should precede splenectomy; tragedies have followed neglect of this precaution, for the leukæmic spleen may wander and its removal is contra-indicated.

Splenectomy may also be the most satisfactory method of dealing with *aneurysm of the splenic artery* or *thrombosis of the vein.*

Whenever surgical intervention is contemplated in pathological states of the spleen it is essential that physician and surgeon should co-operate in determining not only the indications but the correct stage of the disease at which intervention should take place. In addition to the indications already mentioned, there are borderland cases in which the surgeon should be content to act as the skilled craftsman to the dictation of the physician.

Quite apart from conditions in which splenectomy may be definitely indicated there are circumstances in which removal facilitates other surgical procedures. For instance, the writer has often removed the spleen in difficult gastrectomy or in colectomy for extensive carcinoma. Similarly its ablation may facilitate or even render possible the removal of retro-peritoneal tumours or cysts originating about the tail of the pancreas.

Preparation.—This largely concerns the degree of anæmia present. Blood-transfusion may be essential before, during and after the

*F. Rackow, *Brit med. Journ.* 1953 2 1415.

operation and even in the most favourable cases the surgeon should be prepared to transfuse should some unexpected necessity arise. It is essential that the stomach and intestine should not be distended, and the patient should be accustomed to the passage of the stomach tube. Radiotherapy is sometimes employed as a means of reducing the size

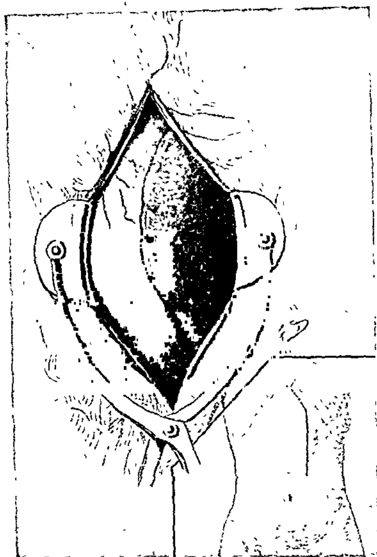


Fig. 420.—Splenectomy : incision and exposure.

of the organ, but should be discontinued at least a fortnight before operation.

Technique.—The operation of splenectomy may be very simple, or may present many difficulties. The latter almost entirely concern the management of adhesions, and the real danger is hæmorrhage. Both the spleen and its pedicle, as well as surrounding adhesions, are easily torn, and the surgeon must be prepared to exercise great care and gentleness. The vessels, especially the veins, are very friable, and the slightest pull or the click of an instrument may tear them. Every

touch of the surgeon must be like a caress and there must be no hurry. Only the hand can lift and manipulate the spleen, and holding forceps are not permissible. Most operators gain increasing respect for splenectomy the oftener they are called upon to perform it. When the organ can be lifted out of the abdominal incision, the operation may be one of the easiest and safest in surgery. But when there are diffuse, firm adhesions, the bleeding is often terrific and the operation most dangerous. In fact, in many of the latter cases it would probably be

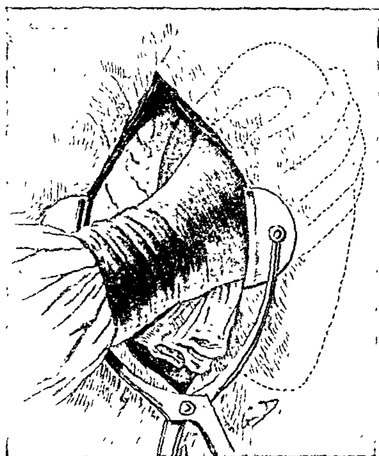


Fig. 421.—Splenectomy : freeing the spleen on its outer surface.

wiser to abandon the attempt to remove the spleen and to be content to diminish its activity by ligaturing as many vessels and as much of the pedicle as can be safely reached. The operation of splenectomy consists of five steps—(1) incision, (2) mobilization and delivery, which may involve freeing many adhesions, (3) securing the pedicle, (4) hæmostasis of the splenic bed, (5) closure of the wound.

The incision.—The principles guiding the surgeon in the choice of incision are to make one free enough to give adequate exposure, so that the separation of adhesions, the delivery of the organ, and the securing of the pedicle can be done without pulling and embarrassment. It must also be large enough to permit thorough examination of

the liver, gall-bladder and stomach. It is a great advantage to be able to separate adhesions under direct observation. The incision giving the best access is a vertical one through the outer third of the left rectus and extending from the left costal margin to or below the level of the umbilicus. This incision must go right up to the costal margin and must extend to three fingers' breadth below the caudal end of the spleen quite irrespective of its total length. The rectus muscle is separated in the direction of its fibres and the abdomen

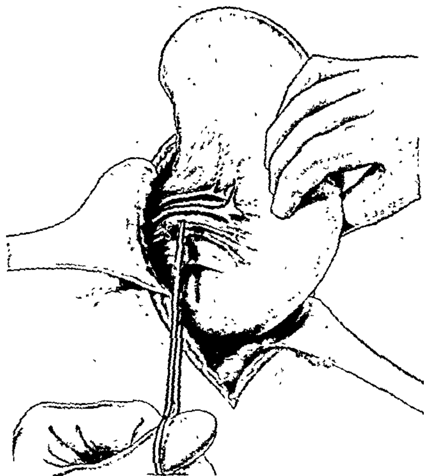


Fig. 422.—Splenectomy. Ligature of the lieno-renal ligament working from below upwards.

opened through the posterior sheath, just as in the right-sided vertical incision for exposure of the gall-bladder. If more room is required, the skin and anterior rectus sheath can be further divided by an oblique extension passing upwards and inwards from the upper end of the vertical incision, just below and parallel to the costal margin. It is rarely necessary to cut across the fibres of the rectus, which can be further retracted after this oblique incision has been made. The incision may be held open by a self-retaining retractor, and any necessary examination of the abdominal organs made. The removal of the spleen is then methodically carried out.

When the spleen is free from adhesions, the organ is delivered from the abdomen before the pedicle is dealt with. When there is only moderate enlargement and no adhesions it is only necessary to slip the hand over the outer surface and to lift the spleen forward. (Fig. 421.) The region of the hilum must always be very gently handled, as the vessels are exceptionally delicate and may readily be torn. There are some few vessels of the vasa brevia, which pass directly from the stomach to the spleen in the gastro-splenic omentum: this must be

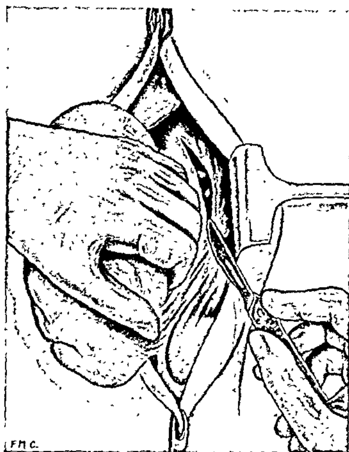


Fig. 423.—Exposure of splenic pedicle from the outer side.
(After Rodney Maingot.)

dealt with first. It is picked up in sections, with its vessels, and either divided between ligatures, or artery forceps are left on the splenic side. This structure having been divided, the pedicle proper—the lieno-renal ligament containing the splenic artery—comes into view, and should be thoroughly exposed, and ligatured in sections, commencing from below and working towards the upper pole (Fig. 422). Before applying forceps or ligatures the position of the tail of the pancreas must be ascertained, for when the lieno-renal ligament is short it may be close to the spleen. In these circumstances it is better to approach the vessels from the outer side by turning the spleen over to the right and incising the posterior layer of the ligament. (Fig. 423.) If the

pancreas is then seen it can be gently thrust aside by gauze stripping. In very exceptional cases, or when there is great urgency, the pedicle may be dealt with by a single encircling ligature, but the best plan is to clamp it in sections and to divide it between the clamps. If the pedicle is not completely caught on the spleen side there is great hæmorrhage. Another plan is to clamp a section of the pedicle on the spleen side, and to surround the proximal part with a ligature passed on an aneurysm needle and securely tied before the intervening portion is divided. This process is carried on until the whole of the pedicle is secured. Great care must be taken not to puncture any of the vessels in passing the ligatures. Interlocking ligatures are not necessary and had better be avoided.

After the spleen is cut away, the pedicle should be carefully inspected. Vessels in any part which are very prominent, or in which there may be any risk of retraction, must be caught separately in artery forceps on the cut surface and surrounded by independent ligatures. The writer prefers chromicized catgut, size No. 0, but many surgeons use silk or linen thread because such materials are supposed to take a better bite. When the pedicle is absolutely dry it may be allowed to drop back into the abdomen. In cases free from adhesions, no hæmorrhage is likely from the spleen-bed, and the abdominal wall may be completely closed. But if adhesions have been separated it is wiser to bring a softened rubber tube or rubber strand from the spleen-bed, simply to provide a track so that the surgeon may be made aware of any unexpected hæmorrhage.

When there are adhesions and the spleen cannot be delivered easily, the surgeon may endeavour to insinuate the hand gently between the outer surface of the spleen and the parietes. When the adhesions are very soft, it may be possible to lift the spleen forward and to turn it over inwards without undue risk. Such adhesions may tear and retract without much bleeding, but on the other hand very considerable oozing may occur in a very short time and occupy the space in which the spleen lay. For this reason the process of separating these soft adhesions and delivering the spleen should not be too deliberate. After withdrawing the organ a large hot moist pack should follow the hand and be thrust into the bed from which the spleen has been lifted. The pedicle is then treated as described. After the spleen has been cut away, the gauze pack is gently withdrawn. During this stage of the operation, the incision is held well open while the stomach and colon are drawn gently to the right and downwards. As the pack is withdrawn, the splenic bed must be carefully inspected for bleeding-points. For this purpose the reverse Trendelenburg position and a headlight are both very useful. Any bleeding-points may be caught in long artery forceps and independently tied, or thrombosed with coagulating endothermy, or they may be occluded by suture, which may pass from one to another if not too far apart, or silver clips may be clamped on each point with a special instrument. Fibrin foam or related substances

are valuable to stay oozing. Should it be impossible to arrest all bleeding in this way, then it is necessary to *pack a gauze strand of* moderate size into the spleen-bed against any oozing areas. The gauze is brought out by the lower angle of the wound and is protected *from contact with the viscera by strands of* rubber tissue; it should not be removed sooner than four days and even then it may have to be taken out by stages to avoid the risk of restarting the bleeding. Should reactionary hæmorrhage occur, the blood will then readily find its way into the dressings, thus establishing the diagnosis at once. When there is no question of hæmorrhage *the incision is usually* completely closed.

The closure of the incision must be carefully carried out in layers with the addition of through-and-through sutures of silkworm gut every one or two inches. Disruption of the incision has not been uncommon after splenectomy.

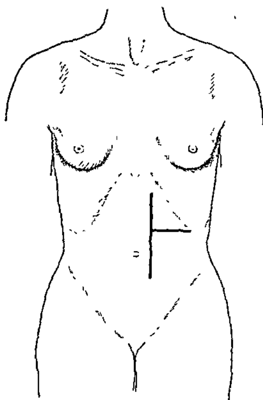


Fig. 424.—Incision for difficult *splenectomy.*

In cases of splenic anæmia of long standing, the adhesions are often so numerous and so strong that it is impossible to separate them in the way mentioned. If there is difficulty in delivering the spleen in consequence, an extension should be made from *the middle of the* vertical incision transversely through the outer half of the rectus muscle and back into the left loin, which it should reach just below the costal margin. (Fig 424) The T-shaped incision *thus made gives an exposure* which is sufficient to deal with any combination of circumstances ever likely to be met with, and it is never necessary to divide the ribs or *to turn up a flap* from the costal margin. With this additional exposure strong adhesions may be clamped, divided and ligatured under the guidance of the eye or they may be divided, while at the same time the hæmorrhage is arrested, by the diathermy knife. Sometimes the spleen is felted to its bed and has to be literally " dug out ". In cases of this kind, if it is impossible to control the bleeding efficiently, the surgeon must not persevere in a foolish attempt to *remove the organ* at all costs. It may be feasible to expose and ligature some part of the pedicle in the hope of thus putting as large an area of the spleen as possible out of action, and this plan has been proposed as an *alternative to splenectomy in difficult cases.*

Bloodless splenectomy.—It has been suggested that ligature of the splenic artery as a first step may render this operation practically bloodless. Only when the spleen is free from adhesions and can be lifted out of the incision can the pedicle be exposed at an early stage, and in such cases the operation presents so little difficulty that with ordinary care it can always be nearly bloodless. In the very adherent cases in which preliminary ligature of the artery might be most helpful, the serious hæmorrhage occurs while the surgeon is carrying out those steps which must precede the exposure of the pedicle. For these reasons this method is not likely to be so successful as it sounds. It may be well to mention here that pictures in works of surgery showing this operation are often extremely misleading.

Splenectomy combined with omentopexy.—Where there is ascites with marked cirrhosis of the liver (advanced Banti's disease) it is always worth while to attach the omentum to the posterior surface of the abdominal wall over as wide an area as possible. If the condition of the patient permits, the complete technique for omentopexy should be carried out (*see* p. 902).

Splenectomy combined with the removal of other viscera.—When splenectomy is required as part of the operation of gastrectomy or removal of the splenic flexure of the colon or nephrectomy, it is much simpler to remove the whole organ than to attempt merely to take away the involved part. If partial removal is adopted there is great difficulty in controlling the hæmorrhage, without any compensating advantage. In performing total gastrectomy it often facilitates the operation to remove the spleen with the stomach, even if it is not involved. There is less trouble with hæmorrhage than if the vasa brevia are dealt with separately. Dislocation of the spleen from its bed very much facilitates the mobilization of the fundus and cardiac end of the stomach.

Comments.—In some cases of long-standing splenic anæmia the abdominal wall is very vascular and there may be quite serious hæmorrhage when the rectus muscle is incised. In these circumstances the diathermy knife may be used, but it may not suffice to stay the bleeding. In this eventuality, a continuous catgut suture, including all the structures but the skin, may be run along either side of the incision and when drawn tight will usually arrest the hæmorrhage. So much blood may be lost in opening the abdomen that blood transfusion at this stage may be necessary. For the removal of the ruptured spleen an oblique incision a finger's breadth below the left costal margin (a left-sided Kocher, Fig. 383, p. 920) and extending from the xiphisternum back into the flank gives an excellent exposure. Some surgeons employ this type of incision for all splenic work, but it is not so convenient for dealing with a really big spleen or if the gall-bladder has to be reached. It is in long-standing cases of splenic anæmia that most difficulty from adhesions is to be anticipated. The surgeon

must be provided with adequate assistance, and his armamentarium must be equal to any call, which will perforce be sudden. Patients of this type should be blood-grouped before the operation, and a suitable donor or a store of blood should be in readiness. In some cases the adhesions contain vessels of considerable size, mostly veins, but occasionally arteries. The vessels of the pedicle may be atheromatous or unusually friable, and it may be difficult to get a good hold for the ligatures.

In a valuable and most useful paper on the Removal of Large Spleens,* A. K. Henry points out that to deliver the spleen from its bed it is necessary to bring the head out first, by inserting the hand between the viscus and the diaphragm (Fig. 425). The novice must

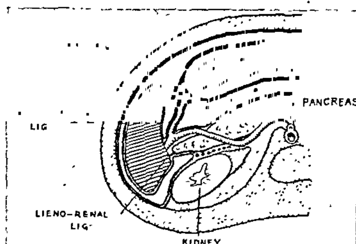


Fig. 425.—The splenic pedicle, showing pre-splenic fold and relation of tail of pancreas.
(After A. K. Henry.)

resist the temptation of trying to withdraw the spleen by pulling on its tail!

The greatest care must be taken in delivering the spleen through the incision for the purpose of exposing the posterior surface of the pedicle. If the organ is large and heavy or the pedicle short, gentle handling is necessary to prevent any sudden pull rupturing the pedicle or tearing into the spleen pulp.

The pedicle can be properly and safely exposed only by systematically dividing the structures which obscure it. Very often the left edge of the great omentum is adherent to the tail of the spleen. There may also be a fat-laden fold of peritoneum, a pre-splenic fold, in front of the gastro-splenic omentum or lesser pedicle. (Fig. 425.) These structures all contain vessels which, if torn, bleed furiously, and the only safe rule is to catch them in artery forceps or to ligature them before division. The late Sir David Wilkie was accustomed to say that all vessels near the spleen should be ligatured at sight, and with vessels

* *Brit Journ Surg*, 1940, xxvii, No. 107, p. 464.

that are so large and so friable this is a good rule. If the parts to be ligatured are caught in artery forceps they ought to be tied at once, as the drag of the forceps or any accidental pull may tear away the vessels in their grasp, with great detriment and annoyance. Let the surgeon recall his Shakespeare—he must have his pound of flesh but not one drop of blood! Vessels that are clearly seen may be surrounded by ligatures passed on an aneurysm needle or a transfixion needle, but no instrument should be blindly thrust through these vascular tissues, as a punctured vessel may be a source of great trouble. The inclusion of the pedicle in a single clamp or mass ligature as shown in

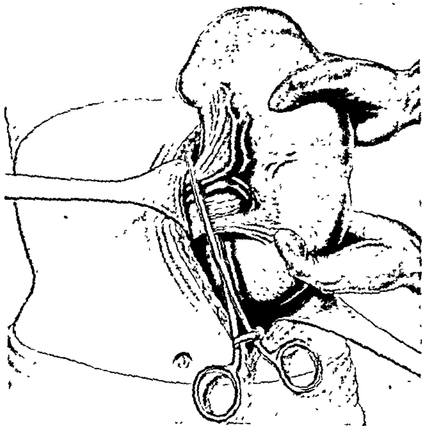


Fig. 426.—The inclusion of the splenic pedicle in a single clamp. This is feasible only if the pedicle is greatly elongated.

some of the old illustrations (Fig. 426) is feasible only if the pedicle is greatly elongated.

These methods are not generally applicable and should not be made an aim.

The close relation of the spleen to the diaphragm has important practical implications. Adhesions fixing the spleen are for the most part attached to the cupola, and bleeding areas are usual on its under surface. In efforts to catch and to tie such areas the diaphragm is easily torn or otherwise damaged, for it is only a thin structure. Vessels that cannot be easily caught in artery forceps should be underrun and ligatured, but the needle must not penetrate deeply or the

pleura may be punctured. Large spleens probably support that half of the diaphragm to which they are in relation and the loss of this support after splenectomy may interfere with the movement and the position of the diaphragm and predispose to chest complications. To mitigate these troubles A. K. Henry tried introducing an inflated rubber balloon into the space previously occupied by the spleen. A limited trial convinced him of the value of this plan, for the convalescence of the patients in which it was used was smoother than others.

It is well to remember that many cases of hæmolytic jaundice harbour gall-stones, and the gall bladder should always be examined by palpation. If calculi are present, they may be removed at the same time if the splenectomy has been easy. When, as often happens, the stones are soft and small, it is only necessary to carry out cholecystendysis (p. 930) but cholecystectomy may be necessary. When there is any doubt about the condition of the patient it is much better to deal with the calculi at a subsequent operation.

In these acholuric cases blood transfusion may be followed by severe reactions and is better avoided. If the condition of the patient is reasonably good splenunculi in the vicinity should be removed as they sometimes hypertrophy and account for incomplete cure or recurrences.

When *aneurysm of the splenic artery* is found it is not enough to remove the spleen unless the vessels are divided and ligatured on the proximal side of the dilatations. *Large abscesses* or *cysts* may have to be drained in the first instance, even if subsequent splenectomy is required. In *hydatid disease* it is much better if the spleen with the parasite can be taken away entire, but not at all costs, for marsupialization through an incision suitably situated for drainage should be quite satisfactory (*see* p. 891).

Complications and after-treatment.—The immediate complications of the operation are shock and hæmorrhage. It must be remembered that in many cases these patients are very poor operative risks, and they may be expected to suffer more from complications than in many other abdominal diseases. When the condition demanding the operation is not associated with any special tendency to hæmorrhage, severe bleeding is a reproach on the conduct of the operation, but the fact that it has occurred in careful hands emphasizes the extreme need for care in splenectomy. In most cases a precautionary blood-transfusion is indicated.

In the few hours immediately succeeding the operation there is often a considerable amount of hæmorrhagic oozing, indicated by the seepage of blood into the dressings or by a steadily rising pulse rate with pallor and restlessness It ought not to be serious, and is probably best treated by blood transfusion and a small dose of morphine, with the idea of keeping the patient and the circulation as quiet as possible. Really alarming hæmorrhage probably means that a vessel has not been properly secured, or that considerable bleeding is going on from a multitude of small points. In either case the only course is to re-open

the wound and to endeavour to secure the bleeding-points under the guidance of the eye, or to pack the cavity from which the spleen has been removed with gauze, either plain or soaked in one of the hæmostatic sera. Again, blood transfusion will be essential and may have to be continued or repeated. In these circumstances it may not be wise to spend time in accurate re-suture of the wound, which should simply be drawn together with a few through-and-through sutures; careful secondary closure can then be carried out when the gauze is removed. If the pancreas has been injured during the operation, local inflammatory mischief with fat necrosis may follow, and may either spread, causing peritonitis, or produce a pancreatic fistula. Because of these sequelæ it is essential to provide drainage to the surface whenever there is any question of damage to the tail of the pancreas. When the usual anterior approach has been employed the drain should be brought to the surface by the shortest possible route through an independent incision in the flank.

There is a tendency to left-sided pulmonary complications in the first forty-eight hours. A slight basal pleurisy has often been noted about the fourth day and may be followed by effusion, but there may be pulmonary collapse or pneumonia. As a rule these conditions clear up without trouble, but occasionally a septic element has evidently been introduced and empyema has resulted.

Hæmatemesis may take place within a few hours of the operation or in the course of the first day or two or even after some weeks. In these circumstances the bleeding is often profuse and alarming, and has been the cause of fatalities. In this emergency treatment is almost limited to blood transfusion. To guard against recurrence, injection of the œsophageal varices carried out through the œsophagoscope, or ligature of the coronary veins and other plans have been tried but the results on the whole are disappointing *(see Vol. II, Œsophagus)*. Thrombosis of the splenic vein may follow the operation and it may spread to the superior mesenteric vessels, causing the classical symptoms of mesenteric thrombosis

Results.—The removal of the spleen for injury may be a very serious matter because of hæmorrhage or the severity of associated injuries. The mortality is about 20 per cent. The after-history of survivors shows that for the most part they enjoy good health and are able to withstand the onslaught of the ordinary diseases like influenza, pneumonia and appendicitis. But a careful study of 100 cases by Ask-Upmark* led him to the conclusion that there was an increased tendency to digestive disturbances, blood changes and unexplained exhaustion. At the present time most removals of the spleen are undertaken for disease, and the prognosis, both immediate and remote, largely depends on the type and stage of the malady for which the operation is carried out. When splenectomy is recognized to be the best, or perhaps the only method of treatment, it should be

* *Acta Med. Scand.*, Suppl. 1936, lxxviii, 226.

performed as early as possible. Immediate mortality is still much too high, due probably to the fact that it is not yet possible to make an exact choice of the most favourable cases. Recent figures from the Mayo Clinic (1930 to 1949 inclusive)* show 747 cases of splenectomy for all conditions with 47 deaths, a mortality of 6·3 per cent. Digby Chamberlain† had 4 deaths in 39 cases; 14 of these were acholuric jaundice, with no deaths. At the present time excellent results are being obtained in *hæmolytic jaundice* and *early splenic anæmia*, with some dramatic successes in the *hæmorrhagic purpura* group.

In hæmolytic jaundice of the congenital type the results, immediate (4 per cent. mortality) and remote, seem to be the best, and in the majority of cases the operation leads to a cure, although the blood fragility persists. In splenic anæmia, operation undertaken before liver involvement has a mortality of about 10 per cent., and recovered cases enjoy much-improved health for a number of years.

* Personal communication
† *Annals Roy. Coll. Surg.*, 1950, vi (March), 158.

CHAPTER XIX

OPERATIONS FOR INTESTINAL OBSTRUCTION

By G. GREY TURNER

INTESTINAL obstruction may be sudden or gradual in onset, or it may present itself as an acute exacerbation of a longer-standing partial obstruction. In the sudden acute obstructions it is the small intestine that is generally affected. Though acute obstruction of the large intestine does occur, as in volvulus, in most cases malignant stricture is the commonest cause and a history of gradually increasing obstruction can usually be obtained. The commonest cause of acute intestinal obstruction is strangulated external hernia, which is considered in Vol. II. In this article only conditions arising from intra-abdominal obstructions will be discussed. Putting aside congenital abnormalities, such as intestinal atresia and imperforate anus, many conditions may give rise to intestinal obstruction, but they may be roughly classified as (1) abnormalities within the intestinal lumen, (2) abnormalities of the intestine itself, and (3) abnormalities obstructing the intestine from without

In the *first* type the characteristic condition is a gall-stone, or much more rarely an enterolith or a mass of undigested food, giving rise to partial or complete obstruction low down in the ileum.

In the *second* type obstruction is not uncommonly caused by tuberculous ulceration, intussusception, polypi either directly obstructing or giving rise to intussusception, mesenteric thrombosis, or volulus and, in the large intestine, malignant growths and volvulus.

In the *third* type the intestine may become attached to or obstructed by tumours, etc , e g , the duodenum by cancer of the pancreas, the small intestine by tuberculous mesenteric glands, the transverse colon in gastric cancer. More commonly, the intestine is obstructed by bands or adhesions resulting from local peritonitis. These conditions may follow a previous operation, as for appendicitis, ovariotomy, hysterectomy, or strangulated umbilical epiplocele. Bands also form between neighbouring coils, giving rise to a " double-barrelled gun " or " concertina " type of deformation. Fortunately it by no means follows that adherent coils are necessarily obstructed. In other cases long bands form, from mesentery to mesentery, from mesentery to gut, from gut to gut, and so on, and these may strangle the coil to which they are attached or a neighbouring coil. In this category comes the *appendix*, the tip of which may become adherent, so that it forms a band attached at each end, and *Meckel's diverticulum*, which may not only form a band but may cause axial rotation of its attached portion of intestine or become inverted into the lumen of the bowel,

giving rise to intussusception. Rare instances are reported of a coil of gut being imprisoned in a hole in the omentum or mesentery, and there are *many retroperitoneal fossæ into which* internal hernia may occur, e.g. the foramen of Winslow, the duodenal, retrocæcal and sigmoid fossæ. The obstruction may be entirely mechanical or it may be combined with strangulation, in which case the blood supply is suddenly arrested. But the distinction is of more academic interest than practical importance for in all operative intervention is required.

There is another important group in which the obstruction, though partly mechanical, is caused by inflammatory involvement of the bowel due to either local or widespread peritonitis. This variety is sometimes spoken of as paralytic ileus, but in that condition there may be no obvious inflammatory cause.

Indications for operation.—There is no doubt that the high mortality attending acute intestinal obstruction* is due in great measure to delay in instituting active treatment. It cannot be too strongly emphasized that it is much more important to make a diagnosis of mechanical obstruction *and act upon it* than to spend valuable time in efforts to make a differential diagnosis of the cause, which may have no bearing on the problems of treatment. The matter can be summed up in a few words: *laparotomy is the only treatment for acute intestinal obstruction, and it should be undertaken at the earliest possible moment.* (But see "Preparation".) The cardinal symptoms are intermittent pain, intestinal vomiting, and cessation of the passage of flatus and fæces. Distension is a comparatively late sign, except in low-down obstructions, and fæculent vomiting is a later sign still. It should be possible to make a diagnosis before either of these signs supervenes, and their presence adds enormously to the difficulties and dangers of the operation. As Sampson Handley says, "fæcal vomiting is not so much a sign of intestinal obstruction as a herald of approaching death."

But there are many difficulties in diagnosis which have a bearing on treatment, especially (*a*) where the obstruction is due to inflammatory disturbances which may subside with time and suitable treatment; (*b*) where the obstruction is adynamic or paralytic, the result of toxins and profound neuro-muscular exhaustion.

The inflammatory type is usually a sequel to peritonitis and is therefore not an infrequent complication of appendicitis. It often accompanies the attempt at localization of an intraperitoneal abscess and frequently disappears when such an abscess suddenly discharges through the wound, into a viscus, or is opened per rectum. These patients often lack the characteristic symptoms of mechanical obstruction, for pain is more continuous than colicky, there is diffuse tenderness, the vomit is not characteristically intestinal and they often void some flatus. The surgeon must be on the look out for some localized abscess which might be opened. During the period of uncertainty it is wise to apply heat effectively to the whole abdomen and to administer

* The average mortality in three widely separated busy surgical centres in England was 15 per cent in 1951. It is probably less than this to-day

small enemata once or twice to keep the lower bowel empty. The stomach should be kept empty by a Wangensteen or Ryle's tube, or the coils of small intestine by the Miller-Abbot tube, while at the same time the water balance and chloride level is being maintained by intravenous injection. In dehydrated patients, large quantities of fluid will be required, but care must be taken not to overload the circulation or pulmonary œdema may result. But it is necessary to add a caution, for even the worst cases of mechanical obstruction will be temporarily relieved by these methods, so that unless there is coincident evidence of a return to normal intestinal function, it is illusory to persevere in their use for more than a few hours.

The adynamic or paralytic ileus type may have an underlying inflammatory cause, but it may also be the result of exposure or handling of the intestines or absorption of toxins from the bowel itself, or of pure nervous exhaustion. It is best treated by rest, by making up for fluid and chloride loss, and by providing nourishment in the form and in quantities which can be assimilated, or by glucose and other nutriments which can be administered intravenously. Such forms of stimulation as will improve the neuro-muscular mechanism of the intestines are valuable. Drugs like strychnine, prostigmin or eserine, in small doses repeated at regular intervals, and diffusible stimulants also are useful. Inhalation of pure oxygen by means of the B.L.B. mask, used continuously for six hours, is one of the latest methods of combating this condition and appears to be helpful. Very often sleep is lacking and if it can be induced by sedative drugs, or indeed by whatever means, improvement often results. If the diagnosis is established beyond question and there is no risk of masking symptoms, small doses of morphine, gr. $\frac{1}{8}$ or $\frac{1}{4}$ repeated every four or six hours, may provide rest and quiescence and help recovery.

When the fact of mechanical obstruction is established it is of great practical importance to decide whether the causative factor is in the small or the large bowel. In the former case an exploratory laparotomy is the proper proceeding whereas in the latter some form of colostomy will probably be indicated.

Preparation.—In nearly every case, two or three hours may advantageously be devoted to preparation. This especially applies to patients who have just been brought into hospital, often after an exhausting journey. One of the first indications is to see that the patient is made generally comfortable, and well warmed. Blankets with hot bottles or electric pads are essential Once an operation has been decided upon, there is no objection to the use of a small dose of morphine (gr. $\frac{1}{8}$ to $\frac{1}{4}$) if there is much pain, otherwise sedatives should not be employed. In addition to these general measures, the indications are: (1) to make up for fluid loss, (2) to restore the depleted chlorides, (3) to counteract alkalosis, (4) to decompress the stomach and upper intestine, and (5) if it has not already been done, to empty the rectum and lower bowel. The first three objects may be attained by the administration of

to bear in mind that distended coils of intestine may be adherent to the peritoneal aspect of the scar and must not be inadvertently opened or otherwise damaged. When there has been no previous operation, a median sub-umbilical incision generally gives the best access An incision of about 4 ins. long may suffice, but in case of difficulty the surgeon must never hesitate to enlarge the wound. Care must be taken to prevent the intestine from prolapsing through the incision, and this is best attained by covering the area with large, moist swabs. It is often impossible to prevent a certain amount of evisceration and in that case great care must be taken to cover the exposed bowel, and to keep the swabs moist by trickling warm saline over them from time to time. As soon as the peritoneal cavity is opened some fluid will be found, and if it is blood-stained strangulation is probably present. Not infrequently the site of the obstruction will at once be disclosed but usually some further search is necessary. Two fingers inserted into the abdominal cavity may quickly discover a mass of adhesions, a coil of tense distended bowel obstructed by a band, a loop passing into a hernial orifice, or a foreign body impacted in the intestinal lumen. Sometimes the source is not so easily found, in which case the bowel must be searched up or down until the obstructed area is located. Collapsed gut takes less harm from handling than distended gut and whenever possible it should be traced. If collapsed gut is not found there is nothing for it but to trace the distended bowel, but in that case the gut is not so easy to handle, readily bruises and is liable to be torn. If it is so much distended that the peritoneum begins to tear, it should be opened for temporary drainage. For this purpose a distended coil is gently withdrawn from the abdomen and a small incision made on the antimesenteric border just large enough to accommodate a 10 or 12 rubber catheter, which is loosely anchored in position by a purse-string suture. If the bowel is not paretic it may be expected to empty fairly well, but if it does not do so the catheter may be advanced further and the bowel may also be milked down towards the catheter, when a good deal of the contents will escape The process may be further assisted by giving a dose of pituitary extract. The coil, with the catheter *in situ*, is allowed to hang over the side of the incision. At a later stage the catheter is removed and the incision closed with the purse-string and, if necessary, one or two Lembert sutures. Moynihan's tube has been recommended for the same purpose but it inflicts too much trauma on the intestine and should now be regarded as only of historical interest The tension having been relieved in this way, the search may be continued with less risk to the intestine. When the site of obstruction has been located the cause must next be ascertained.

Obstruction by adhesions and bands.—These cases vary from the simplest V-shaped angulation at a single point or combined with torsion or the most complicated mass obstructions When the seat of the obstruction is found a decision has to be arrived at on the following points:

(1) Is it a case of angulation, or of strangulation, where gangrene threatens?

(2) Can it be dealt with by simple separation of adhesions or division of a band?

(3) If more extensive methods are necessary, must the affected loop be short-circuited or resected?

(4) Should drainage of the intestine, whether temporary or protracted, be instituted?

Strangulations are usually obvious because of the deep blue or sometimes almost jet-black colour of the intestine. This is nearly always due to a band, herniation through an aperture, or mesenteric thrombosis. Bands sometimes give way on the slightest handling or they may be very tough and require division by knife or scissors. Any long band should be excised and not merely divided, lest it should cause further obstruction. The condition of the gut must be carefully inspected; the changes which may be found and the treatment required are exactly the same as in strangulated hernia. (Fig. 427.) (See Vol. II.) If adhesions are the cause, these should be separated under the guidance of the eye as far as possible, for the gut is so easily torn during blind separation. When the involved area is at the bottom of the pelvis the Trendelenburg posture may be a great assistance. The intestine at the site must be carefully inspected after the separation. Sometimes there are many points of adhesion and the separation must be continued until it is certain that the obstruction is completely relieved. Where the adhesion is to an old tuberculous gland the intestine is particularly likely to give way. Any hole into the bowel must be carefully repaired by suture though, if there is a tendency to a free escape of bowel contents, the bowel should be brought outside the abdomen and allowed to empty itself as completely as possible before closure. More frequently, only the peritoneal coat is torn but it may be torn in numerous places. If shreds of peritoneum can be easily replaced and fixed by a point of suture so much the better, but if this is not possible and the condition demands that the operation should be terminated without delay these areas may be allowed to look after themselves, provided always that the lumen has not been opened. If there are many raw areas with free bleeding this may be controlled with fibrin foam or saline poured into the cavity so that the peritoneal surfaces will be kept apart for some hours Usually the abdomen can be closed without drainage, but if any considerable abscess has been

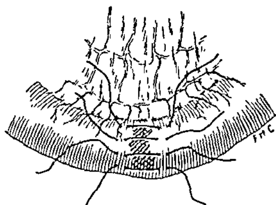


Fig. 427.—Area of small intestine, damaged by pressure of a band or adhesion, being tucked in by Lembert sutures.

opened it is wise to bring a rubber tissue drain from it and out at the lower end of the parietal incision. Sometimes several coils of intestine are so closely adherent that it is well nigh impossible to separate them. In these circumstances it is best to short-circuit the area by lateral anastomosis but no greater area of bowel should be excluded than is essential. Resection is seldom required except where there has been strangulation. Only very rarely is external drainage of the small intestine required, and enterostomy with its risk of dangerous sequelæ should be avoided whenever possible. As a rule, a rapid closure of the parietal incision is required, and for this purpose a continuous suture of the peritoneum, followed by through and through interrupted sutures of silkworm gut or nylon or wire for the other layers are effective and safe.

Treatment of mass obstructions.—In these cases many coils may be bound together by adhesions in what seems, and often is, an inextricable tangle. This type of obstruction is perhaps most often met with as the result of caseating tuberculous mesenteric glands, or of pelvic peritonitis following appendicitis. Attempts to separate the adhesions will almost always be unsuccessful, and if persisted in will

additional risk in leaving the mass in the abdomen. The correct procedure, therefore, is to *short-circuit the obstruction*, making a lateral anastomosis between two coils of gut, one on either side of the obstruction. It is necessary to exclude as small an amount of intestine as possible, therefore it is important to make the union between a coil just above to one just below the obstruction. It is sometimes impossible to expose unobstructed small gut below a mass of adhesions in the lower ileum. In such circumstances the union may be made between the small bowel above the obstruction and the cæcum. There may be a temptation to completely exclude the involved area by dividing the bowel and making an end-to-side anastomosis but lateral union has the advantage that after the obstruction settles down some of the intestinal contents may find their way through the normal channel and that, if the obstruction is absolutely complete, the piece of bowel between the anastomosis and the obstruction can regurgitate its contents to the anastomosis rather than become dangerously distended with infected mucus (see Fig. 451, p. 1073) In mass obstruction, where the involved area can be freed from the parietal peritoneum and brought outside the abdomen, resection with immediate anastomosis may be the best course.

Strangulation by bands.—In these cases the constricted gut suffers just as the coil of gut does in a strangulated hernia, i.e. there is not only obstruction of the lumen but interference with the blood supply and, if unrelieved, the condition goes on to gangrene (Chap. XXII). The site of obstruction must be exposed and the constricting band divided.

The loop is then examined, as in strangulated hernia, to estimate its viability. The lines of constriction at the two ends of the loop are examined, and also the loop itself. If the constriction has not bitten into the gut, if the loop has retained its glistening appearance, and if it shows signs of revival after being wrapped up for a few minutes in a hot swab, it may be expected to recover, even if considerably congested. If, however, the lines of constriction are deeply cut or ulcerated, or if the loop has lost its polish, is limp or toughly œdematous, and more especially if it shows patches of what is probably commencing gangrene, it cannot be expected to recover, and *enterectomy must be carried out.* End-to-end anastomosis is the best way of restoring continuity of the bowel (*see* p. 1055). There is no reliable alternative to this course, for though the offending loop may be withdrawn from the abdomen, anchored there, and opened, thus creating a fæcal fistula, the case usually ends fatally, as the result either of continued toxæmia or the loss of intestinal contents. Even if the amount and quality of the fluid lost are kept replaced the condition is precarious and death is often merely delayed. It is for the same sort of reasons that a deliberately made enterostomy should be employed very sparingly. The latter cause is especially operative when the opening has to be made higher than about three feet above the ileo-cæcal valve. Subsequent attempts to close the fistula have been attended by a high mortality.

Mesenteric venous thrombosis.—This is one of the most lethal varieties of obstruction, with a mortality of about 50 per cent. When encountered at operation, resection of the involved gut is usually necessary in spite of the extent of the condition.* Continuity must be restored by end-to-end anastomosis. To guard against extension of the thrombotic process after the operation, treatment by heparin should be instituted immediately and continued for some days.†

Post-operative prevention of adhesions.—A great deal of work, both clinical and experimental, has been done on this problem. It is first necessary to recognize that the principal causative factor is infection rather than trauma. None the less, anything that injures the delicate endothelium of the peritoneum is harmful, and all intraperitoneal manipulations should be conducted with great gentleness. Gauze held in sponge handles should never be screwed round in an effort to clean up some area There is some doubt whether blood in the peritoneum leads to the formation of adhesions or whether it may have just the opposite effect. While it is certainly not necessary to irrigate the peritoneum in an attempt to remove all blood, it is best to remove masses of clot. These are best " baled out " with the hand The aspirator, commonly spoken of as the " sucker ", is most useful for removing fluids, but it should not be too powerful and should be used with discretion, as it may injure gut that is forcibly drawn up against its nozzle. Rough gauze swabbing should never be used.

* Grey Turner, *Lancet* (1937), April 3rd
† Lulse, *Lancet* (1943), May.

Adhesions which have to be broken down after some intraperitoneal inflammation are not so likely to re-form as is often supposed. With these reservations, it is well to recognize that as far as possible all areas denuded of peritoneum and all raw or rough areas should be covered by peritoneum or by some organ, as for instance when the uterus or a loose pelvic colon is turned back over a raw area in the bottom of the pelvis. When neither of these plans can be employed, the omentum may be used as a protective, either as it is or in the form of an isolated graft. Another plan is to prevent structures that might become adherent, such as intestine, from coming into contact until at least a certain amount of repair at the traumatized region has taken place Incidentally it is surprising in how few hours such areas are covered by lymph, which soon organizes and in turn becomes covered by endothelium. To keep viscera apart until this reparative process gets started, normal saline left in the peritoneal cavity probably serves the purpose as well, or better, than anything else Various substances like oil, and protective materials like cargile membrane, thin rubber or cellophane, have been tried, but there is little or no evidence to show that they attain their object. The most recent method is to treat raw areas with some preparation of fibrin, but whether this attains the object of forming a protective layer is not clear.

RETROPERITONEAL HERNIA

During the development of the intra-abdominal organs, changes of position occur, especially of the stomach and duodenum, of the mesentery and of the cæcum, and fusions take place between peritoneal layers on the posterior and lateral walls of the peritoneal cavity. As a result, at certain points folds and fossæ occur which may be large enough, or become large enough, to contain intestine, and it happens from time to time that a coil of gut, entering one of these fossæ, becomes constricted and strangulated. Many names have been given to these fossæ, of which a great many have been described. The subject was well reviewed by Moynihan and Dobson.* From the surgical point of view, those of most importance are the paraduodenal fossa of Landzert, into which the left duodenal hernia passes, and the mesenteric-parietal fossa of Waldeyer, which is the site of a right duodenal hernia. A few cases of hernia occur into fossæ around the cæcum and appendix, into the intersigmoid fossa, and even into the foramen of Winslow, through which a large amount of the small bowel may find its way into the lesser sac

In this type of hernia the sac may be large enough to contain the whole of the small intestine, so that there are symptoms of very high obstruction without abdominal distension. From the operative point of view importance lies in the fact that the necks of the fossæ are generally closely surrounded by blood-vessels. Thus the neck of the paraduodenal fossa has the inferior mesenteric vein in the upper

* "Retroperitoneal Hernia," 2nd Edn, 1906

horn, and the left colic artery in its lower. The neck of the fossa of Waldeyer has the superior mesenteric artery and vein in its anterior margin. It is therefore a critical proceeding to enlarge the ring to release the hernia, and closing the ring to prevent a recurrence is equally dangerous. Fortunately, there is rarely any difficulty in withdrawing the intestine from the sac, but when there is, the neck should not be nicked but should be stretched with a director followed by the finger. Should the intestine be reluctant to leave, the surgeon must make pressure on the sac while at the same time gentle traction is made on the entering bowel, not on the mass but on one or other of the separate pieces. It may be necessary to puncture and empty some of the coils of contained intestine to diminish their bulk. For this purpose it is convenient to introduce a rubber catheter into the gut through the puncture and to surround this with a purse-string suture which can be tied as the catheter is withdrawn.

The diagnosis is seldom made before operation, the abdomen being opened for obstruction. The treatment of the constricted intestine is on the same lines as in strangulated hernia elsewhere (Vol. II).

OBSTRUCTION BEYOND THE CÆCUM

Blind cæcostomy.—A good deal of discussion has ranged around the question whether the surgeon should be content to make a blind cæcostomy or whether this should be preceded by an exploration of the abdomen. The answer depends on the situation of the obstruction,* the condition of the patient, and the degree of abdominal distension. If the surgeon is able to determine definitely before operating that the obstruction is beyond the cæcum then there can be no objection to making a blind cæcostomy. The only real risk is that the surgeon might open the cæcum when he ought really to be dealing with an obstruction in the small bowel No one will deny the advantages of a general exploration in cases in which a cæcostomy is necessary as a part of the management of obstruction due to a malignant growth of the large bowel. It is a great advantage, for instance, to ascertain whether or not the condition causing the obstruction can be dealt with there and then, or if there must be a second operation, and whether at such an operation radical interference will be possible or only some further palliative measure, but no such exploration can be safely carried out with a very ill patient or a much distended abdomen and the rule should be when in doubt don't explore. In some patients the diagnosis is made sufficiently early for the exploration to be made in safety, even though it can only end with a cæcostomy as the first stage of a subsequent operation for the removal of a growth. In other cases the abdomen is much too distended and the patient is far too ill to permit a general exploration. In these circumstances blind cæcostomy should be performed. Between these two extremes

* To elucidate this, more use may be made of plain radiographs of the abdomen with the patient both on the back and erect In acute obstruction in the large bowel the lesion will probably be a carcinoma in the colon in about 90 per cent of cases.

there are cases in which the experience and judgment of the surgeon must help him to decide what course to pursue. If blind cæcostomy is decided upon, the surgeon must be satisfied, after having exposed the cæcum, that the obstruction is in the large bowel. If there is any doubt, the parietal incision must be enlarged so that the small intestine may be explored. If the cæcum is empty and collapsed, the obstruction is in the small intestine; if the cæcum is tense and distended, the obstruction is below that part of the bowel.

Exploration for large bowel obstruction.—There are few causes of large-intestine obstruction other than volvulus or malignant stricture, and volvulus, whether of the cæcum or of the sigmoid, is usually obvious immediately the abdomen is opened. The probability is that a malignant stricture will be found and the colon must be examined from below upwards, because growths causing obstruction are much more common in the left colon than in the right. When the seat of obstruction is found it will be recognized by the change from collapsed to distended intestine, but the growth will often be small and of the constricting type, and may be overlooked if the surgeon is expecting to find a considerable tumour. Having been located, the growth is examined to make sure that a loop of small intestine is not adherent to it and obstructed, as happens occasionally in cancer of the descending colon. The liver must be examined for secondary deposits, and if they are absent the growth is more carefully examined to determine the prospects of a subsequent operation for its removal. The wound is then closed, and a separate incision made either in the right iliac fossa, the distended cæcum being brought up to the wound and opened or above the umbilicus for transverse colostomy. When the growth is not considered removable, or if this point is in doubt, two other courses are available. When situated above the pelvic brim a lateral anastomosis may be made between the cæcum, or some other proximal part of the colon, and the bowel below the growth. If situated at the pelvic brim or just beyond, a colostomy may provide the best form of relief or will suffice to drain the bowel and to provide for physiological rest in the hope that after a period of a few weeks the conditions around the growth may have so much improved as to bring it within the range of palliative removal. When a second stage radical removal is contemplated, some surgeons prefer to make a defunctioning type of colostomy (Devine). In these circumstances the writer considers that cæcostomy though not defunctioning provides a sufficient protection, and it has the very great advantage that, having served its purpose, it can be easily and safely closed at a single sitting. The main indication for cæcostomy is a completely obstructed colon with over-distension. If these conditions are not present, adequate preparation with the sulpha drugs and antibiotics will render the proceeding unnecessary.

Technique of cæcostomy.—This is best performed under general or local infiltration anæsthesia, though with the latter method there is a risk of necrosis of the wound edges, probably encouraged by the

fæcal contamination which is bound to occur. A Ryle's tube should be used to diminish the risk of regurgitation. The parietal incision should be an oblique one across a line from the anterior superior iliac spine to the umbilicus and at the junction of its outer with its middle third. (Fig. 428.) In spare subjects an incision of two inches or even less will suffice, but it may have to be 4 to 6 inches long in the obese. The peritoneum is opened and the cæcum identified; in handling the latter the surgeon must remember that, if it is much distended, it may be readily injured, and that sutures will not be easy to apply without tearing. The next step is either to open the cæcum and tie in a Paul's tube or to fix the bowel to the parietes for opening after it has become securely adherent, or to open the bowel and to fix the edges of the opening to the margins of the skin incision there and then.

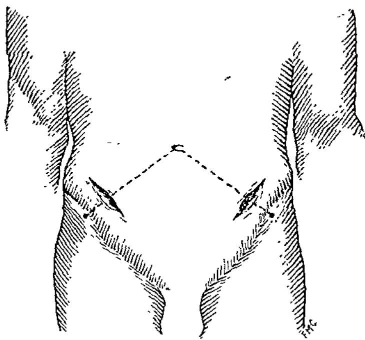


Fig. 428.—Incisions for cæcostomy and colostomy.

If there is any difficulty in bringing the cæcum into the wound because it is too tense from distension it is safer to puncture it *in situ* with a trocar and cannula. With the escape of gas and perhaps liquid fæces, the cæcum becomes flaccid, and in this state it must be held with forceps and withdrawn from the incision with the cannula still retained The latter is not removed until the bowel has been safely fixed to the parietes. The cæcum, having been fitted into the wound, is attached to the edges of the peritoneum by a few points of catgut suture. Another method is to draw the ends of the abdominal incision together with a stitch which also takes a bite of the wall of the bowel but without entering its lumen. In either of these ways an area of the cæcum like half a tangerine orange is fixed outside the abdomen. This may be opened immediately if the obstruction is well marked, or deferred for

48 hours so that the peritoneal cavity may be securely shut off by the formation of plastic exudate.

The opening in the bowel should be about an inch long in the summit of the part exposed. This suffices for the insertion of a moderate-sized Paul's tube, which is securely tied into the bowel with strong silk. If the area of the cæcum is not sufficient for tying in the tube, the edges of the incision in the bowel may be fixed by stitches to the edge of the wound, or the skin beyond, at about four equidistant points. This method is satisfactory, and there is no special risk of infection of the parietes. It has the disadvantage that there is no means of conducting liquid fæces away from the area during healing.

Semi-solid fæces may cause a block in the Paul's tube which it is difficult to release. Irrigation with warm water or a weak solution of peroxide of hydrogen may suffice, or it may be necessary to remove the rubber tube and to pass a catheter up the glass tube to help to break up the mass and to secure better access for irrigation. If these measures fail, the tube should be removed from the bowel as free escape of the contents is essential for the comfort of the patient. A Paul's tube loosens at the end of a week or ten days, and should then be removed. By this time, whichever method has been employed, the cæcum will be well exposed beyond the level of the skin, and the greater part of the intestinal contents will find a ready exit. The bowel beyond can be easily irrigated from the cæcal opening, and it may also be possible to wash it out through a rectal tube, the fluid returning through the cæcostomy.

Difficulty in bringing the cæcum outside the wound.—This may be due to excessive distension, to the absence of a meso-cæcum or to pathological adhesions. Sometimes it is possible to mobilize the cæcum by dividing the peritoneum on the outer side where it is reflected on to the posterior parietes, and by separating the cellular tissue with the finger. If the cæcum is much distended there is great risk of the cæcum bursting on manipulation or being torn, and in these circumstances some other part of the large bowel proximal to the obstruction should be opened—most conveniently the transverse colon. When the obstruction is in the ascending colon, ileostomy may have to be substituted for cæcostomy.

Safety-valve cæcostomy.—In this method a large-sized rubber catheter (No. 14 or 16) is fixed into an opening in the cæcum and slightly buried in the bowel wall by two or three surrounding purse-string sutures. (Fig 476, p. 1151.) This may be done without withdrawing the cæcum from the abdomen, or it may be returned, and anchored to the parietal peritoneum by one or two sutures. Though this method has its uses in the treatment of peritonitis it cannot be recommended for the relief of obstruction or as a preliminary to the removal of bowel growths, as decompression and drainage of the bowel is seldom complete.

It is to be remembered that cæcostomy *in any form is only a temporary* expedient, and is not intended for permanent drainage. Indeed, drainage of *the cæcum and right colon* is attended with so much discomfort, owing to the fluid discharge, that a permanent opening on this side should be avoided whenever possible.

Colostomy.—Where the character of the obstruction makes it probable that the drainage must be *permanent*, colostomy is indicated. The intestinal contents become less and less fluid from above downwards, the fæces becoming formed at or about the middle of the transverse colon. A fluid fæcal discharge over which the patient has no control is very trying, so that colostomy is rarely done except in the transverse or the left colon, obstructions of the right colon being overcome by ileo-transverse anastomosis, if that is possible. Colostomy is always made on the front of the body by *the transperitoneal route.* The lumbar method has nothing to recommend it, and is now obsolete. In addition to the greater ease of the anterior operation, it has the enormous advantage that the opening is in a position where it can be seen and attended to by the patient.

Inguinal colostomy.—This operation is merely for the purpose of draining the colon and no exploration of value can be conducted through the small incision which is all that is necessary for making the colostomy It is not a good plan to enlarge this incision for *exploration*, as *hernia is almost certain to follow and a colostomy* opening perched on the top of a ventral hernia is very unsatisfactory. If exploration is required, a separate sub-umbilical incision should be made. As grave issues often depend on this exploration, it may be necessary to put the patient in the Trendelenburg position and to inspect as well as palpate the growth. When this midline incision is employed, the separate small incision required for the colostomy may be more easily made *from the outside when the fingers of the hand inside the abdomen* are used to make its wall *prominent* at the site for the incision. This method is sometimes spoken of as a stab wound, but anything so suggestive of violence is unworthy of a place in modern surgery. The best place for colostomy is an oblique incision in the left iliac fossa not too near the iliac spine. (Fig. 428.) It should be made across the junction of the outer with the middle third of a line drawn from the anterior superior spine to the umbilicus. *Some operators prefer* an incision through the rectus muscle or at its outer border. Whatever its situation, the incision should be as small as will suffice, but its length will depend on the build of the patient, for in very stout subjects it must be longer than in those that are spare. The object of making *a short incision is to* prevent prolapse of the small intestine by the side of the colostomy, to diminish the risk of prolapse of the colostomy itself, and to prevent subsequent hernia at the site *Some surgeons* use a muscle-separating incision under the mistaken idea that it gives the patient a measure of voluntary control ; such an approach hampers the surgeon and may constrict the bowel so much as to lead to

gangrene of some part of the loop. The peritoneum having been opened, the large bowel must be identified and withdrawn from the abdomen. On occasion it may be difficult to find the bowel, and the incision may have to be enlarged for the purpose. In rare cases it has been necessary to inject air or fluid per rectum to distend the bowel for identification. The common mistake is to look for the bowel too far towards the centre of the abdomen. generally speaking, and especially when the mesosigmoid is short, it will be found below and external to the incision and nearer the iliac spine. The large bowel is usually recognized easily by its longitudinal bands and appendices epiploicæ, at least in this situation, but it may be difficult to draw it outside the abdomen, and this may depend on the shortness of the mesosigmoid or on adhesions which are very common on the outer side. Adhesions can usually be exposed and divided, thus mobilizing the

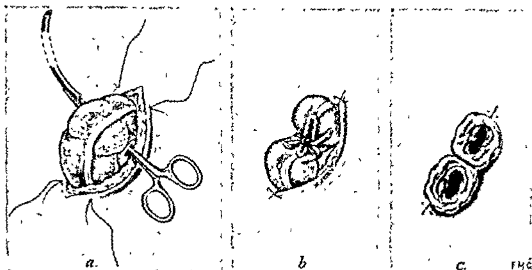


Fig. 429.—Technique of colostomy.

a Artery forceps as colostomy rod, with rubber tube *b* Rubber tube has been tied round loop over the opening made by cautery to let out flatus. *c*. The completed colostomy

bowel. In the rare cases in which the mesosigmoid is so short that the bowel cannot be withdrawn even after mobilization it is better to make an independent transverse colostomy. The bowel having been identified, it is necessary to select a portion which will leave four or five inches of sigmoid above the opening as a fæcal container.

With the small parietal incision which is commonly employed to-day there is very little risk of prolapse, and, in any event, as often as not prolapse is of the lower segment of the bowel. Having selected the bowel to be utilized, it must be withdrawn until the antimesenteric border is level with the abdominal wall. To prevent it from retracting into the abdomen and to ensure the formation of a good spur, an old pair of artery forceps is passed through the mesentery from the umbilical side; this is better in every way than the glass rod which is sometimes recommended, as forceps are always to hand and glass objects may break. (Fig. 429, a) Some surgeons attain the same object by

putting a stout silkworm mattress stitch through the incision and the mesentery of the loop, while others draw the abdominal wall together beneath the loop after sufficiently dividing the mesentery and controlling the vessels. It is next necessary to fix the bowel at either end of the incision to prevent more than has been selected from escaping from the abdomen. A silkworm stitch is passed at either end including the skin and the aponeurosis of the external oblique ; it then secures a good bite of the bowel through one of the longitudinal bands, but without entering the lumen, and traverses the same tissues on the opposite side. When the epiploic appendices are large or numerous, and especially if they are unusually pendulous, it is wise to ligature them near the bowel and to cut off the excess. Though this is not essential, it is helpful in convalescence, for though the appendices always gradually shrivel up, the process may take a long time. As a last step in the operation, a piece of strong rubber tubing about $\frac{3}{16}$ in. in diameter and 10 in. long, is caught in the forceps which have been passed under the bowel, for use as described later. The bowel is then covered with a piece of green protective or old rubber glove and dressings are applied. During the first 48 hours, if flatulence is very troublesome, it may safely be relieved by a dose or two of opium, but at the end of that time, when the peritoneal cavity may be expected to be safely shut off, a puncture is made in the summit of the colostomy with the cautery. This allows gas to escape and usually makes the patient quite comfortable. This puncture may be made at the time of the operation if the bowel is much distended, and if the obstruction is really acute a freer opening must be made and a Paul's tube tied in. In an ordinary case, at the end of a week, the artery forceps is withdrawn through the mesentery, carrying with it the rubber tube. (Fig. 429, b.). The latter is tied as tightly as possible around the bowel just below or over the puncture previously made. In about 48 hours the elastic pressure cuts through the bowel painlessly and without hæmorrhage, and provides a very convenient way of opening the colostomy. (Fig. 429, c.) This method was devised by Professor Rutherford Morison and has proved entirely satisfactory.

Sometimes the elastic stops short of complete division of the gut, but when this is so, any tissue left in the grasp of the ligature is crushed and avascular and can be divided with the cautery or even with the scissors without much risk of hæmorrhage. In order to prevent the fæcal contents from getting into the lower segment, it is necessary to divide the bowel completely in this way. Should the colostomy be intended to be only temporary, complete division of the bowel is not usually considered necessary and its lumen may be cut half across on the convexity, or a longitudinal incision into the lumen may be employed. In this event the elastic ligature is not indicated. As a matter of fact, even for temporary colostomy, it is better to divide the bowel completely, or fæcal matter will be sure to reach the lower end. In actual practice it is as easy to repair a complete colostomy as the sort of fæcal fistula into which a partially divided bowel degenerates.

Paul's method of colostomy.—In this operation the summit of the

selected loop is brought up to the abdominal wall but is not withdrawn from the abdomen. The base is stitched all round to the peritoneum and transversalis by a continuous suture of catgut. A circular or elliptical portion of the whole of the bowel wall not more than an inch in diameter is excised from the summit of the loop and the margins of the opening so made are sutured to the skin of the parietal incision. The opening is made piecemeal and is stitched to the skin bit by bit, to diminish the risk of contamination. The orifice should not be larger than will comfortably admit a finger. Mr. Paul always held that this type of colostomy gave the best result, though it is admitted that contraction of the opening is more likely to follow than in the type in which the whole bowel is brought out on to the abdominal wall To prevent contraction, the patient is directed to wear an aluminium colostomy plug, which is retained in position by a pad of wool and a belt.

Transverse colostomy.—The incision of about two inches long is made either in the middle line or through the left rectus muscle just above the level of the umbilicus. A convenient and satisfactory method which makes for subsequent cleanliness is to combine excision of the umbilicus with the opening of the abdomen. The transverse colon varies very much in position but the omentum provides a guide. A loop of colon is brought out of the incision and the omentum attached to it is removed or sufficiently freely separated to allow if its being returned to the abdomen. The gut is then fixed to the parietes as described for inguinal colostomy. The question of the opening of the gut and its subsequent management are exactly as in inguinal colostomy. Occasionally the mesocolon is so short that the bowel cannot be brought out of the wound; the surgeon must then either be content with a fæcal fistula into the colon or must make an independent cæcostomy.

Defunctioning or disconnecting colostomy of Devine.—*The principle* of this operation is not only to divide the colon completely across at the site of the colostomy but also to bring the ends through independent openings on to the abdominal wall separated by a bridge of one or two inches of skin and subcutaneous tissue. By this means, the fæcal current is completely diverted from the distal part of the bowel, but the open end of the latter remains for drainage, irrigation and other purposes.

Technique.—The method is usually employed in the transverse colon. The loop of the colon to be used is brought through a paramedian incision and the corresponding omentum is separated from it and returned to the abdomen after careful ligature of the vessels. The mesocolon is then divided vertically downwards from the under surface of the middle of the loop for about three inches. Just below the limit of the resulting gap in the mesentery the loops of the colon are sutured together over a length of three or four inches Two independent incisions are then made through the skin and subcutaneous tissue down to the aponeurosis about $1\frac{1}{2}$ inches from the edge of the upper part of

the median incision. These openings should be not more than about 1 to 1½ inches in length and are connected by subcutaneous burrowing superficial to the aponeurosis, with the midline incision. The latter is then carefully closed snugly up to and around the loop of colon. Finally, the latter is divided with the cautery about the centre of the loop and each end is brought through its respective tunnel and allowed to protrude for about ½ inch beyond the skin, in which position they are fixed without tension by a few sutures.

If there is an element of obstruction, a Paul's tube may be tied into the proximal end; otherwise the open ends can be protected by plain or petroleum jelly gauze.

Modifications of colostomy.—These are generally devised in the hope of affording some measure of control over the artificial anus, but it must be admitted that even partial control by sphincteric action is rarely if ever obtained. By any method the patient may, and usually does, acquire a " habit " so that he knows when the bowel is likely to act and can be prepared. To acquire this habit takes time, often many months and sometimes as long as one or two years. A permanent colostomy for non-malignant conditions or after successful excision of the rectum for cancer need be so little of an encumbrance that patients can engage in ordinary occupations with comfort and confidence. It was hoped that if the oblique muscle-fibres of the internal oblique were separated, as in McBurney's appendix operation, or if the loop of sigmoid flexure was brought out through the rectus muscle, a sphincteric action would result. In the Lilienthal method the bowel is divided, the upper end rotated axially 180–360° according to the thickness of the wall, and the twisted gut retained in that position by suture A tube is tied into the upper end for a distance of 6 in. and kept there for a week. Lilienthal maintained that the narrowed lumen resulting from the rotation constituted a partial sphincter.* Many other plans have been devised and tried out, but none can be relied upon to secure even a measure of voluntary control.

Accidents that may attend colostomy.—Sometimes the small intestine or omentum escapes by the side of the large bowel and prolapses through the wound to a considerable extent. The escaped bowel may become strangulated. This accident usually occurs in the few hours immediately after the operation, but it may take place the next day or—in feeble subjects—as long as a week afterwards. Such an accident can be guarded against by making the parietal incision no larger than is absolutely necessary for the loop of large bowel, and also by fixing the latter to the edges of the wound It must be treated by cleansing the prolapsed bowel, returning it to the abdomen and putting a few additional sutures through the parietal incision. The small bowel may also be strangulated around the colostomy, i e between the attached sigmoid and the parietes, within the abdomen This accident is more likely when the large bowel is brought through the rectus muscle,

* *Ann Surg*, 1910, lii, 384.

Gabriel* reported five cases, all of which proved fatal. He suggests that inguinal colostomy should be made near the anterior superior spine and that the sulcus on its outer side should be closed by a purse-string suture as suggested by Rankin of the Mayo Clinic. The writer has never known this accident occur when the incision is made not more than an inch and a half internal to the anterior superior spine.

The colostomy opening may retract into the abdomen.—This may happen quite suddenly or may develop gradually. It can only occur in cases in which there is no support through the mesentery or after the latter has been removed. It is more likely to take place when the mesosigmoid has been very short and the bowel is retained in the wound at considerable tension. Cases are recorded in which it has happened after the bowel has been opened, and sometimes the bowel contents have been discharged into the peritoneal cavity. Even in the latter circumstances, with prompt intervention, it has been possible to cleanse the abdomen and to remake the colostomy, with recovery of the patient; none the less it is a most serious accident and great pains should be taken to guard against it.

Gangrene of the loop of bowel has usually followed a very small opening in the abdominal wall such as may result from a tight muscle-splitting incision. As a rule it remains strictly limited and can be dealt with by cutting away the necrosed part of bowel. Occasionally an infective process has spread into the abdomen and caused fatal peritonitis.

Phlebitis of the mesenteric vessels has led to death from portal pyæmia. It can neither be foreseen nor prevented, but it is well to bear in mind the general rule that in the presence of potential infection large venous trunks should not be perforated by sutures or other foreign bodies.

Abscesses in the abdominal wall round about the colostomy opening occasionally occur. They do not show much tendency to spread, though cellulitis, and even gas gangrene are not unknown.

Extensive ulceration of the skin around the colostomy opening is common only in cases of dysenteric infection, but it may occur in tuberculosis In cases in which it appears soon after the formation of the colostomy and progresses rapidly, the possibility of amœbic dysentery should be borne in mind, for this yields rapidly to treatment by emetine. Sometimes it is merely a consequence of inanition, in which case it may be expected to recover as the patient's general condition improves.

Sequelæ of colostomy.—Stricture of the orifice is the only common condition met with in these days This is to be expected if it is not possible to bring the loop of bowel completely to the surface, or in deliberate operations of the Paul type. But it may happen even when a portion of bowel is brought completely out of the wound, for sometimes a sclerosing process goes on around the opening until the latter may be no larger than will admit a quill The explanation of this state of affairs is not obvious. Strictures of the first type can usually be prevented by dilating the opening with the finger and directing the

* *Proc Roy. Soc Med*, June, 1928, xxi, 1433.

patient to wear a special dilator for some weeks after the operation. When serious contraction occurs as a late sequel it is usually necessary to remake the colostomy. For this purpose an oblique incision is made including the contracted orifice in an ellipse about its centre. The incision is deepened with care as the bowel may be herniated just beneath the skin. When reached, the bowel must be sufficiently freed from the parietes, the peritoneum being freely opened, to allow the loop with the colostomy to be withdrawn and fixed in the wound without tension and with its summit well beyond the skin surface. The adherent ellipse, with the contracted orifice, is then removed with a sufficiency of the convexity of the bowel to leave an opening which will easily admit two fingers. Some vessels may have to be caught and tied or the whole margin of the opening may be oversewn with a continuous catgut. The margins of the new colostomy must be half an inch above the skin level as a precaution against further contraction. Any sign of the latter process is an indication for regular dilatation.

Prolapse of the colostomy used to be frequent, but is not often seen nowadays. Probably it was encouraged by too large a parietal incision. As often as not, it is the lower loop of bowel which prolapses and this fact shows that it is not essential to pull down the upper bowel as far as possible, and if this is done it robs the patient of the advantage of a fæcal container. The only satisfactory treatment is excision of the prolapsed bowel.

After-care of colostomy patients.—As a rule, when colostomy has been carried out as part of an operation for the radical treatment of cancer of the rectum, the patient acquires a very satisfactory " habit " which makes the care of the colostomy comparatively straightforward. When, on the other hand, the colostomy is merely a palliative operation, the patients rarely acquire this " habit " and they are often further distressed by continued discharge from the growth per rectum or by regurgitation through the colostomy. There is no definite plan which will ensure the " habit ". In time, patients discover for themselves the type of diet and the general régime which leads to its development. Usually the bowel may be expected to evacuate at such a time as the bowels were accustomed to move before the operation became necessary. It is convenient to endeavour to form a habit by which the colostomy acts just after breakfast and perhaps once again in the evening, but not during the interval. Some patients have slight discharge after each meal but quite often this is only mucus. There are many colostomy belts on the market and some of them appear to be quite satisfactory, but most tend to draw the exposed bowel into the cup-like apparatus and may keep it œdematous or unduly vascular, and sometimes they seem to encourage prolapse. A great many working class patients prefer to rely on a simple home-made apparatus, which is usually some type of many-tailed bandage or a flannel belt tied with tapes. The exposed bowel is protected by a vaselined cloth, and a ring of cotton wool, covered by a cap of the same material, forms a sort of receptacle which they appear to find efficient.

An ordinary good-fitting abdominal belt with a shallow cup-shaped receptacle which can be laid over the colostomy makes a good outfit. The necessary cotton wool can be adjusted around the cup and all kept in place by the belt. The parts round about the colostomy should be kept clean with ordinary soap and water; antiseptics are not necessary, though an occasional application of a spirit lotion may harden and preserve the skin. After cleansing and drying the skin, it is a good plan to dust on some toilet powder. Disorders of the bowel attended by diarrhœa are best dealt with by confining the patient to bed until the looseness of the bowels is overcome by diet and the necessary medicinal treatment. Constipation must be met by regulation of diet and the well-known remedies, but an enema of hot water into the colostomy opening may be the best help. Some few patients find it best to empty the bowel each morning by such an enema.

Operations for closure of colostomy.—The method of destroying the spur by the pressure of a special clamp, in the expectation that the colostomy will spontaneously close thereafter, is tedious and troublesome for both patient and surgeon and often not very successful, and is now seldom used.

There are two main operative methods which may be used:—

(1) Formal excision of the portion of sigmoid with the colostomy and restoration of continuity by end-to-end anastomosis.

(2) Direct repair of the colostomy opening by suture after complete mobilization of the colon from the parietes.

The latter plan is the more difficult and, now that the peritoneal cavity can be freely opened with so little risk even in the vicinity of a polluted area, it would appear to have no special advantages. It may get over a difficulty in those cases where the sigmoid scarcely exists and there is very little bowel available or where the mesentery is very short. Though either of these plans should be very safe both have occasionally been followed by death, and when such a calamity occurs it is the more poignant because the operation for closure of a colostomy is usually the concluding stage of a series of interventions of considerable magnitude.

Technique. **Excision of the colostomy.**—The abdomen is freely opened by an oblique incision enclosing the colostomy opening in an ellipse which includes the skin and subcutaneous tissue. The bowel can usually be readily separated from the gap in the muscle, only a few snips with scissors being necessary, though the surgeon may have to incise densely adherent muscle here and there. The bowel is freely mobilized, the actual opening in the colon being covered with a mop or otherwise protected. When freely exposed, the bowel wall must be cleared for an inch or an inch and a half above and below the colostomy site. At these points the bowel may be lightly clamped This tends to make a cleaner operation and provides a convenient handle for manipulation of the bowel, but the clamps are not essential The

bowel is then divided completely with slight obliquity. A small section of the meso-sigmoid may have to be excised, thus freeing the segment to be removed. The vessels in the meso-sigmoid must be clamped before being divided and are securely ligatured. Interlocking ligatures are quite unnecessary but the surgeon must see that no uncaught vessel is allowed to retract. The bowel ends are then approximated and the anastomosis completed by end-to-end union as described (pp. 1055–1064).

The slightly oblique division of the bowel ensures that there is no narrowing of the lumen at the site of the anastomosis. The suture line may be further protected by fixing one or two neighbouring appendices epiploicæ over it. The bowel is then replaced in the abdomen and the parietal incision is carefully closed by interrupted sutures Careful closure is essential as there seems to be an especial tendency to muscle weakness or hernia. If there is any doubt about the adequacy of the anastomosis, a rubber strand should be brought from the neighbourhood to the surface and left *in situ* for at least four days. If the anus is very tight it should be moderately dilated or a tube of forefinger size should be left through the anus for three or four days.

Direct closure by suture of the colostomy opening.—This is not usually an easy operation, and always requires a considerable degree of nicety. Although the skin round about is sodden and fæcal-soiled, the parts will have acquired a local immunity by the time the operation is necessary and there is really very little risk of infection and as a rule the wound heals quite well. Any attempt at preliminary cleansing is best carried out with soap and water followed by the use of some spirituous antiseptic solution. The parts are so sensitive that general anæsthesia is indicated. It may be possible to close the bowel without opening the peritoneum, but there is not the slightest need to make that a criterion, and it is usually much easier if the peritoneum is opened. Whatever method is employed, an incision encircles the colostomy opening very close to the bowel and is deepened until it reaches the parietal peritoneum. Often the bowel is so closely adherent to the parietes that it runs the risk of being opened or torn during the separation, and therefore this step must be carried out carefully and under the guidance of the eye: any small tears in the bowel must be carefully repaired When the peritoneum is reached it may be possible to loosen it from the muscles without actually opening the abdominal cavity, but generally speaking this is impossible and it is easier to open up and divide the peritoneum all round the bowel so that the surgeon can withdraw the latter from the abdomen. The edges of the mucous membrane must next be defined, and sometimes this requires knife or scissors, as they may have become everted. Having been defined, the edges must be drawn together—the upper to the lower—by a continuous suture of chromicized catgut which is conveniently passed from the mucous membrane. In this way further eversion is avoided and less of the intestine is required for the union, so that the lumen at the

point is not too much narrowed. This continuous suture must then be protected and further inverted by *stitches passed Lembert-fashion*, and finally the whole union is reinforced by tacking some of the appendices epiploicæ or adjoining loose tissue over the suture line. The bowel may then be allowed to retract into the abdomen, or gently pushed back if the operation has been extraperitoneal. The defect in the abdominal wall should be carefully repaired in layers by interrupted sutures with the addition of two or three through-and-through silkworm or other reliable sutures. If the surgeon has any doubt of the efficiency of the bowel suture, he should bring a small tissue drain from the neighbourhood of the repaired bowel to the surface.

About 48 hours after the closure of a colostomy the patient may develop some obstructive symptoms, such as colic with distension, vomiting and inability to pass flatus. These are due to swelling of the bowel at the site of the closure and usually subside in a few hours. They are to be treated by withholding food and giving a dose of opium, and not by purgatives or enemata. If they do not spontaneously subside it usually means that the colostomy will re-open. All being well, about the fourth day the patient may commence to take liquid paraffin and as a result the bowels will commence to act, though the process may need to be assisted by a glycerin enema. When flatus is voided at an early stage the operation is sure to be successful. If things are not going well there will be inflammatory mischief around the wound which will probably break down, the colostomy being spontaneously re-established. Of course, the incision may have to be deliberately re-opened. Sometimes a small fæcal fistula forms but heals of its own accord.

[illegible] tion was brought to the notice of the [illegible] Weir had made the original suggestion,† [illegible] and constipation, and it has since also been used for drainage in large-intestine obstruction and for irrigation in dysentery. It has also a limited application as a means of relieving tension in the large bowel after a difficult resection and anastomosis. It has a great advantage over cæcostomy in that there is no risk of soiling the peritoneum, and bowel leakage is sometimes prevented, presumably by the valve of Gerlach or can be controlled by a suitable-sized catheter worn *in situ* in the appendicostomy opening.

Technique.—The abdomen should be opened by McBurney's incision (Figs. 468, 469, 471, pp. 1125–8), and the appendix identified and shown to have a patent lumen The cæcum at the base of the appendix is attached to the edges of the peritoneal incision by a few interrupted sutures, the greatest care being taken not to constrict the artery in the meso-appendix. The appendix is brought out, and the remainder of the peritoneal incision closed. The wound is closed by a few interrupted silkworm-gut or other sutures above and below the appendix,

* *Proc. Roy Soc Med.*, 1908, ii, Surg Sect., p 67.
† *Med. Rec.*, August 9, 1902, lxii, 201.

taking up skin and aponeurosis of the external oblique. A suture attaches the appendix to the skin, or a safety-pin may be passed through the meso-appendix at the skin level. The redundant part of the appendix is amputated, and a rubber catheter passed through its lumen into the cæcum. When the time arrives to close the fistula it is only necessary to remove the remains of the appendix, as in formal appendicectomy.

INTUSSUSCEPTION

By intussusception, the name introduced by John Hunter, who first described the condition in 1789, is meant the slipping of one section of the bowel into an adjoining, generally distal, section. It is most commonly due to disordered peristaltic action, the exciting cause for which has been much discussed but is still in doubt. In other cases, usually in adults, a tumour of the bowel, e.g. a polypus, acting as a foreign body, excites peristalsis, with the result that the tumour is passed along the bowel, carrying with it and invaginating its attached segment into the bowel immediately below. A malignant growth of the ileo-cæcal valve may be intussuscepted to a point beyond the splenic flexure. Sometimes Meckel's diverticulum is inverted into the bowel and causes intussusception, but these cases are rare. In a series of 40 cases, in addition to the malignant case mentioned, there were but 2 cases due to polypus, one of which was a papilloma in the colon, and the other an inverted Meckel's diverticulum.

The usual type of intussusception, due to disordered peristaltic action, occurs at or near the ileo-cæcal junction, and is peculiarly a disease of early life, the vast majority occurring in children under five years. The accepted age of onset is about six months. In Fitzwilliam's analysis of 1,000 cases 72 per cent. occurred in patients under one year.* There were very few before the third month, a steady rise to the sixth, a rapid fall to the eighth, and a further steady fall to the twelfth. Males are more often affected than females (Fitzwilliam, males 68 per cent., females 32 per cent., or in cases under 12 months, males 3 to 1). In the majority of cases the patients are well-developed, healthy, breast-fed babies.

Indications for operation.—It must be remembered that in the early stages the obstruction is not always complete, so that there is not a typical picture of intestinal obstruction. The babies cry and are evidently in pain, vomiting is usual but not insistent, and there is very rarely abdominal distension. Most cases, however, begin abruptly with an attack of severe pain and collapse, from which they soon recover. The classical sign, the passing per anum of blood and mucus, is sufficiently constant to be looked upon as pathognomonic, but it is not always present in purely enteric intussusception nor in any case at a stage at which the diagnosis ought to be made and acted upon by prompt operation. A tumour can be felt in the majority of

* *Lancet*, February 29 and March 7, 1908, i, 629 and 709.

cases, and in practice the diagnosis is easy and a high average of correct diagnoses is reached. Early operative treatment has yielded by far the best results, and no time should be lost in trying to reduce the intussusception by inflation, gravitation enemata, or other means.

Preparation, etc.—Many of these cases are considerably shocked and later dehydrated and in these circumstances it may be wise to spend even some hours in overcoming these conditions before operation. Similar measures may be required both during and after the intervention and should not be delayed. The principal measures are the use of plasma or serum intravenously, followed by saline as chloride deficiency must be corrected. Frequent small quantities of glucose drinks interspersed with plain water by the mouth are also of great value especially after operation. In dealing with such very ill children who are obviously bad risks it is most helpful to be able to secure the co-operation of someone skilled in pædiatric practice.

Technique.—Babies stand exposure and handling of the abdominal contents badly,so that for successful intervention the operation should be completed quickly, great care and gentleness being exercised throughout. The anæsthetic is therefore a very important factor, as much time may be lost in closing the abdomen if relaxation is incomplete. General anæsthesia by the methods in current use by experts is entirely satisfactory. In any case, the administration should not be commenced until the surgeon is quite ready to open the abdomen and should be discontinued the moment the last stitch in the parietal incision has been securely tied. Because of the risk of vomiting, with possible aspiration into the lung, it is wise to pass a catheter into the stomach by the nasal route before the anæsthetic is administered, and to leave it in position until some time after operation Every effort should be made to minimize shock, and the child's arms and legs should be completely wrapped in cotton wool and resuscitative measures should be employed throughout the operation. The abdomen is opened in the median or paramedian line by a vertical incision extending for three inches below the level of the umbilicus There is nothing gained, and probably a good deal lost, by making too small an incision, for speed is essential, and the operator must not be hampered by want of space in finding and reducing the intussusception. But a general escape of the small intestine through the wound should be avoided if possible, and this is much easier with an incision of only moderate size. After opening the peritoneal cavity the contents are protected and restrained by a large flat swab laid over the wound and two fingers are introduced and the intussusception felt for and located. If the apex has not passed the splenic flexure, the whole tumour can generally be lifted or coaxed out of the abdomen, and this should be done whenever possible, as it facilitates reduction.

When the apex of the intussusception has reached the descending colon it must be pushed up by the first and second fingers of each hand, the left steadying the intussuscipiens, the right pushing up the apex.

This may be difficult if the apex has actually reached the pelvic colon or rectum, though otherwise it is usually easy. In the few cases where the apex has reached the anal canal it may be pushed up by an assistant with the fingers in the rectum until the pelvic colon below the apex can be grasped by the surgeon working in the abdomen, with a finger and thumb or sometimes the whole hand. As soon as possible the tumour should be withdrawn and received into a hot moist towel.

If reduction can be brought about by manipulation with the fingers without withdrawing the intussusception from the abdomen, so much the better, provided the surgeon can be absolutely sure that it is complete.

When the intussusception is exposed, reduction is rapidly undertaken, the intussuscipiens being held in the palm of the left hand while the fingers knead the intussusception backwards, the right hand steadying and replacing the ensheathing layer as it is delivered of the



Fig. 430.—Reduction of intussusception by gentle squeezing (left hand) and gentler pulling (right hand).

intussusceptum. (Fig. 430.) Reduction is generally easy and rapid until the last inch or so is reached, when it becomes more difficult, owing to the tension on the ensheathing layer and œdema of the remaining portion, the apex, of the intussusceptum. Gentle pressure on the apex will eventually lead to reduction, though possibly the serous coat of the ensheathing layer may give way at one or two places. While the pressure and manipulation of the intussusception is being continued, the gentlest traction on the entering intestine is helpful and permissible. Strong pulling never does good and may seriously damage the bowel. When reduction is difficult, gentle but firm steady pressure exerted through gauze covering the whole intussusception will help to disperse œdema and may render a repeated attempt at reduction successful. Dilatation or stretching of the neck of the intussusception, with either a pair of blunt pointed forceps like a small slough holder (Daw), a flat hernia director or even a little finger, is not usually very helpful and is apt to result in tearing Once

cases, and in practice the diagnosis is easy and a high average of correct diagnoses is reached. Early operative treatment has yielded by far the best results, and no time should be lost in trying to reduce the intussusception by inflation, gravitation enemata, or other means.

Preparation, etc.—Many of these cases are considerably shocked and later dehydrated and in these circumstances it may be wise to spend even some hours in overcoming these conditions before operation. Similar measures may be required both during and after the intervention and should not be delayed. The principal measures are the use of plasma or serum intravenously, followed by saline as chloride deficiency must be corrected. Frequent small quantities of glucose drinks interspersed with plain water by the mouth are also of great value especially after operation. In dealing with such very ill children who are obviously bad risks it is most helpful to be able to secure the co-operation of someone skilled in pædiatric practice.

Technique.—Babies stand exposure and handling of the abdominal contents badly, so that for successful intervention the operation should be completed quickly, great care and gentleness being exercised throughout. The anæsthetic is therefore a very important factor, as much time may be lost in closing the abdomen if relaxation is incomplete. General anæsthesia by the methods in current use by experts is entirely satisfactory. In any case, the administration should not be commenced until the surgeon is quite ready to open the abdomen and should be discontinued the moment the last stitch in the parietal incision has been securely tied. Because of the risk of vomiting, with possible aspiration into the lung, it is wise to pass a catheter into the stomach by the nasal route before the anæsthetic is administered, and to leave it in position until some time after operation. Every effort should be made to minimize shock, and the child's arms and legs *should be completely wrapped in cotton wool and resuscitative measures* should be employed throughout the operation. The abdomen is opened in the median or paramedian line by a vertical incision extending for three inches below the level of the umbilicus There is nothing gained, and probably a good deal lost, by making too small an incision, for speed is essential, and the operator must not be hampered by want of space in finding and reducing the intussusception. But a general escape of the small intestine through the wound should be avoided if possible, and this is much easier with an incision of only moderate size. After opening the peritoneal cavity the contents are protected and restrained by a large flat swab laid over the wound and two fingers are introduced and the intussusception felt for and located If the apex has not passed the splenic flexure, the whole tumour can generally be lifted or coaxed out of the abdomen, and this should be done whenever possible, as it facilitates reduction.

When the apex of the intussusception has reached the descending colon it must be pushed up by the first and second fingers of each hand, the left steadying the intussuscipiens, the right pushing up the apex.

This may be difficult if the apex has actually reached the pelvic colon or rectum, though otherwise it is usually easy. In the few cases where the apex has reached the anal canal it may be pushed up by an assistant with the fingers in the rectum until the pelvic colon below the apex can be grasped by the surgeon working in the abdomen, with a finger and thumb or sometimes the whole hand. As soon as possible the tumour should be withdrawn and received into a hot moist towel.

If reduction can be brought about by manipulation with the fingers without withdrawing the intussusception from the abdomen, so much the better, provided the surgeon can be absolutely sure that it is complete.

When the intussusception is exposed, reduction is rapidly undertaken, the intussuscipiens being held in the palm of the left hand while the fingers knead the intussusception backwards, the right hand steadying and replacing the ensheathing layer as it is delivered of the



Fig. 430.—**Reduction of intussusception by gentle squeezing (left hand) and gentler pulling (right hand).**

intussusceptum. (Fig 430) Reduction is generally easy and rapid until the last inch or so is reached, when it becomes more difficult, owing to the tension on the ensheathing layer and œdema of the remaining portion, the apex, of the intussusceptum. Gentle pressure on the apex will eventually lead to reduction, though possibly the serous coat of the ensheathing layer may give way at one or two places. While the pressure and manipulation of the intussusception is being continued, the gentlest traction on the entering intestine is helpful and permissible Strong pulling never does good and may seriously damage the bowel. When reduction is difficult, gentle but firm steady pressure exerted through gauze covering the whole intussusception will help to disperse œdema and may render a repeated attempt at reduction successful. Dilatation or stretching of the neck of the intussusception, with either a pair of blunt pointed forceps like a small slough holder (Daw), a flat hernia director or even a little finger, is not usually very helpful and is apt to result in tearing. Once

this process starts it cannot be controlled and in a moment much trauma may result. Small tears limited to the peritoneal coat are not a matter of great concern but if there is any question of injury to the mucous membrane an efficient repair by suture must be carried out. A much bruised and torn piece of intestine often quickly recovers but it is an additional assurance to wrap it in omentum before returning it to the abdomen.

Reduction will be complete when the appendix, in the ileo-cæcal variety, is seen to be free to the base of its mesentery or in other parts of the bowel when the " dimple " on the outer wall is pressed out. The intestine is examined for injuries to the serous coat, any necessary repairs are done by a suture here and there and the parts returned to the abdomen. In intussusception about the cæcum, the commonest site, the appendix after reduction may look very much congested or even be quite black from hæmorrhagic infarction. If the child is in good condition, such an appendix may be removed, but this step is not really necessary, for wonderful recoveries are the rule. If after reduction the involved area shows signs of gangrene at isolated spots, generally small black areas with lustreless serosa, these may be oversewn with safety. *If there is frank gangrene of considerable areas,* or the reduced part is in a precarious condition in which later gangrene is inevitable, resection and anastomosis may be carried out. Only a few years ago this proceeding in young children was almost invariably *fatal but with the supportive and restorative methods now available* the outlook is much better and many recoveries have been recorded. The parietal incision is closed with continuous suture of the peritoneum and through-and-through silkworm-gut or other reliable sutures for the remainder, *the stitches being placed not more than half an inch apart* and securely tied. They should not be removed sooner than ten days later even if they are " cutting " into the soft parts. If the wound bleeds when one or two stitches have been removed the others should be left *in situ* for a few more days. *Bursting of these wounds used to* be fairly common and it is a wise precaution to strap the abdominal wall as soon as the sutures are out.

Irreducible intussusception.—In certain cases it may be impossible to reduce the intussusception, and in others, where reduction has been possible, the gut may have been so damaged, either by its long strangulation or in the attempt at reduction, that its viability is doubtful. What *course should be adopted ?*

1 *Resection of the affected area.*—This method takes a longer time than can be safely spent on abdominal operations in most babies and even to-day is likely to be followed by a considerable mortality. In older children and in adults resection is the method of choice. It generally involves excision of the ileo-cæcal angle with part of the ascending colon and restoration by end-to-end union. This operation has no outstanding difficulties, especially in a patient who probably has a long mesentery, but it cannot be done very quickly, and is not

usually undertaken until some time has been spent in attempts at reduction. It may be completed by the Paul-Mickulicz method. (Hindmarsh.) The operation is, however, perfectly justifiable, and is often considered the best way out of a difficulty.

2. *Short circuit by lateral anastomosis.*—This method theoretically has great disadvantages for it leaves the intussusception untouched, and in addition takes time which might be better employed in carrying out resection. None the less it has proved very successful and may yet prove to be safer than resection in very young infants.* If the intussusception appears to be in a condition of impending gangrene, or if its condition is doubtful, it should be wrapped in omentum after the anastomosis has been made. It is also wise to bring a rubber drain from the neighbourhood to the surface.

3. *A fæcal fistula may be made in the intestine proximal to the intussusception.*—This method has little to recommend it, as it leaves the intussusception unreduced and introduces a dangerous complication. It should only be done as a last resource in a patient too ill to stand any more time-consuming method.

The spontaneous cure of intussusception, by sloughing of the intussuscepted part which is subsequently passed, is so rare that very few surgeons have seen a case, and the few recorded examples are almost legendary.

Choice of operation.—Whenever it can be carried out, reduction is always the best plan. Should it prove impossible, or should much damage be inflicted on the intestine in the process, short circuiting by lateral anastomosis with omental protection of the involved bowel is the best course to adopt in children up to about 5 years of age. In older subjects resection holds out a good prospect and can be employed with confidence.

Chronic Intussusception

This condition is very rare and is usually met with in older children or adults. It may be possible to effect reduction safely but the patients are often suffering from the toxæmia of chronic intestinal obstruction and in these circumstances a two-stage operation holds out the best prospect. When the small intestine is involved, lateral anastomosis, followed in ten days to a fortnight by reduction or resection, will be the correct procedure. In the large intestine, the first stage should be drainage of the bowel by cæcostomy and later reduction, followed by removal of the causative factor, or resection of the involved segment

Intussusception in Adults

This is commonly produced by a bowel growth or an inverted Meckel's diverticulum

After reduction, the causative factor, if not obvious, must be searched for and be dealt with. As a rule, bowel resection will be indicated

* Elliot-Smith, *Lancet*, Nov. 2, 1935.

(Chap. XX). When a diverticulum is the cause, it may be everted in the process of reduction of the intussusception. If the point of attachment to the bowel is narrow, the diverticulum alone may be excised, care being taken to close the resulting incision in the transverse axis of the bowel in order to avoid the formation of a constriction. Should the base be very wide or the attachment be on the mesenteric side, the portion of bowel bearing the diverticulum should be resected, continuity being restored by end-to-end union. If the diverticulum does not become everted and the bowel is in good condition, its lumen may be opened and the diverticulum ligatured off and removed like a polypus, the outer peritoneal dimple being oversewn Lembert fashion. In other circumstances, when the cause is a polypus or even a malignant growth, resection of the bowel will be the safest course.

Results.—Intussusception, although attended with a considerable mortality, shows on the whole better results than any other form of acute intestinal obstruction. This is undoubtedly due to the fact that diagnosis is relatively easy and cases are now submitted to operation promptly, for here, as in all cases of intestinal obstruction, the result depends almost entirely on the interval elapsing between onset and operation So many factors affect the issue that it is impossible to say what the minimum mortality should be. Delay in operating, age of the patient, resistance to shock, the anæsthetic, and lack of skilled preparation and after-care, are all points affecting the question apart from the condition found and the difficulties encountered. Resection up to three years of age has proved a very serious proceeding, with a high mortality, but this reproach should be ascribed to late intervention rather than to poor technique. In the late Mr. Carson's series of 40 cases there were 6 deaths, a mortality of 15 per cent. One was colocolic intussusception in a patient of 36 years, due to a polypus, another had an intussusception starting at a Meckel's diverticulum, and 2 required resection, so that of this list only 2 uncomplicated cases died.

The mortality of operations for acute intussusception in children in these days is probably well below 10 per cent. In a valuable paper, Morrison and Court* state that in their series operation during the first twenty-four hours was attended by a mortality of only 5 per cent.; this rose steeply to 20 per cent when intervention was delayed until after the second day They also found that the mortality rose with the site, being highest in the purely enteric variety.

It is said that the *risk of recurrence* is so great that no operation for intussusception is complete unless steps have been taken to prevent it. This is not the general experience and, indeed, in the writer's own experience of many years, only one recurrence took place among patients of the ordinary infant type, where the intussusception is believed to be due to disordered persistalsis It therefore seems fair to conclude that in children no special precautions to guard against recurrence are indicated. Some surgeons† recommend fixation of the

* Morrison and Court (1948), *Brit Med J*, I, 776
† E. S. Judd and J. C. Masson (1943), *Proc. Mayo Clin*, 18, 333

base of the appendix exteriorized through a separate stab incision. In cases where there is a definite pathological condition, e.g. a polypus, a Meckel's diverticulum, a mass of glands at the ileo-cæcal angle, or a growth of the ileo-cæcal valve or in the colon, such must be dealt with. But these cases occur in older patients, where there is a reasonable chance of recovery from an extensive operation.

VOLVULUS

Volvulus of the *small intestine* is extremely rare in Great Britain but not uncommon among natives of East Africa.* The condition usually involves the whole mass of small bowel, and the exact diagnosis is only made on exploration. The treatment is to undo the twist after the abdomen has been opened. It is difficult to prevent the involved coils escaping from the abdominal incision: they are usually much distended, sodden and heavy with their content of undigested vegetable food. As there is a great tendency for the peritoneal coat to tear they must be very carefully handled and have often to be decompressed by temporary enterostomy. For this purpose a large rubber catheter should be inserted with a purse-string suture surrounding but even so the contents may have to be milked out. As the catheter is withdrawn the purse-string is tied and supported by additional Lembert sutures. Only prompt operation can prevent a very high mortality.

Volvulus of the *large intestine*, on the other hand, is not so very uncommon. It is practically confined to the cæcum or the sigmoid flexure, the latter being by far the more frequent site. It occurs generally in adult life, and gives rise to a severe form of acute obstruction with marked local distension. In many cases it is found in association with a mild degree of so-called congenital idiopathic dilatation of the colon. The rotation of the cæcum is more limited than that of the sigmoid, rarely exceeding a quarter-turn, while the sigmoid may be rotated through one or more complete turns.

Volvulus of the cæcum.—The abdomen should be opened in the median subumbilical line. The incision should be free, so as to allow accurate observation of the twist and easy manipulation. If possible, the whole mass should be lifted out of the abdomen. The twist is generally clockwise, i.e. from the patient's right to left, and after inspection to confirm its direction it must be systematically untwisted, the mass being taken between the two hands and rotated in the reverse way. If it is impossible to see which way the twist goes, a tentative unwinding should be done from left to right, when it will soon be evident whether it is being unwound or not. When the volvulus has been undone some step should be taken to prevent recurrence, to which there is a definite tendency, though perhaps more in the sigmoid than in the cæcum. Not infrequently it is found that a band of adhesions crosses the anterior surface of the colon at the point

* Kerr and Kirkcaldy-Willis (1946), *Brit. Med. J.*, 1, 799.

where the cæcum was twisted, and this band requires division or removal. Recurrence will probably be prevented by sewing the cæcum into the right iliac fossa, the sutures passing through the outer longitudinal band or even through the anterior if there is a marked tendency for the cæcum to fall towards the midline, and fixing the cæcum by suture to the peritoneal reflection on the posterior wall of the false pelvis. If the cæcal distension does not disappear after reduction of the volvulus, it may be punctured and its contents evacuated, the puncture being closed by suture, or converted into a small cæcostomy.

Volvulus of the sigmoid.—Treatment is carried out on the same lines. Here again the twist is probably from the patient's right to left, but the distension is more extreme, and thickening of the mesosigmoid often makes reposition more difficult and recurrence more likely. The incision, in the median or paramedian subumbilical line, must be a long one, as it is desirable to get the whole mass outside the abdomen. Sometimes distension of the involved loop is so extreme that this is obviously impossible. In such a case the bowel may be opened on its summit and the contents evacuated, care being taken to safeguard the wound. The mass having been lifted outside the abdomen, the twist is unwound as described above. Gangrene of the loop would demand excision, but this is rare.

Some of these cases look very complicated, but the only way is to unwind the twist when the most involved-looking mass will straighten out if methodically rotated in the right direction. When after reduction the loop is found enormously distended, congested and sodden, a small colostomy should be made into the summit. A Paul's tube is tied in and the area is sutured to the middle of the parietal incision. Patients sometimes get so much relief from the colostomy that they are content to keep it permanently, but of course it can easily be closed by suture if desired. To prevent recurrence the summit of the loop may be sutured to the abdominal wall, or an anastomosis may be made between the upper and lower limbs.

But recurrence often occurs despite the measures that may have been taken to prevent it. Resection of the sigmoid with end-to-end anastomosis or by Paul's method is then the correct treatment, sometimes preceded for greater safety by temporary cæcostomy.

GALL-STONE ILEUS

These concretions may become impacted in any part of the intestine, but the usual site is the ileum within 2 ft. of the ileo-cæcal valve. They are usually safely voided if they reach the colon, though impaction in the large bowel may occur (*vide infra*). Sometimes the calculus is arrested by a pathological stenosis, and there are specimens in the museums showing gall-stones often as large as a hen's egg impacted in a stricture due to cancer of the large bowel. Plain X-ray of the abdomen may occasionally help in diagnosis.*

* Lee *B.M.J.*, 1945, I, 555.

In this form of obstruction early operation is most important for the high mortality is almost entirely due to late intervention and not to any difficulty inherent in the operation or after-care.

Technique.—The necessary intervention can often be carried out with local anæsthesia and, as the patients are often elderly and in poor condition, this is a considerable advantage. The abdomen should be opened by a median incision below the umbilicus. With a couple of fingers introduced into the cavity the foreign body is usually readily located, though it may be necessary to trace the intestine up or down in order to find the exact site of obstruction. The treatment then consists in withdrawing the intestinal coil containing the foreign body from the abdomen, inspecting it to be sure that the bowel shows no sign of pressure necrosis, and, if it is sound, gently pushing the stone upwards until it reaches a portion of the intestine less implicated in the obstruction. The intestine is gently clamped a little distance above the stone and, the wound having been guarded with care, a longitudinal incision is made on the antimesenteric border over the foreign body and large enough to allow the stone to be extracted without bruising the edges of the incision. Very often the stone cannot be moved in the intestine and the latter must be incised at the point of impaction. The opening in the gut is closed in the transverse axis of the bowel to avoid the risk of narrowing the lumen. It is not necessary to drain the intestine. In rare cases the gut suffers from pressure necrosis, and enterectomy must be performed. If the site of obstruction is very low in the ileum it may occasionally be possible to push the calculus on into the cæcum in the expectation that it may then be voided naturally. Impacted calculi cannot be safely crushed or broken up *in situ*.

Obstruction by masses of undigested food or foreign bodies is to be treated on similar lines.

When gall-stone ileus is met with there is often an internal fistula between the gall-bladder and some part of the alimentary canal. There may also be one or more calculi in the gall-bladder itself. These pathological considerations raise the question of interference with the gall-bladder either at the time the obstruction is dealt with or as a deliberate subsequent intervention. The answer is supplied by the knowledge that recurrent obstruction or subsequent gall-stone attacks are very rare There is the further consideration that patients suffering from gall-stone ileus are often very ill and any extension of the operation would be an unwise proceeding.

Results.—This condition often occurs in old and feeble women who are poor surgical risks, and although the operation is easy and can be done very rapidly, there has often been a mortality of over 50 per cent. This is largely due to delay in diagnosis and operative treatment. The writer had three deaths in fifteen operations for this condition. In one case the calculus which was impacted in the colon measured 7 inches in circumference and weighed 5 oz. The patient, an old gentleman of 81, recovered* and lived in comfort for seven more years.

* *Brit Journ Surg*, 1932, xx, No. 77, p. 26.

ENTEROSTOMY

This is the name given to the operation of opening the lumen of the small intestine on to the surface for the purpose of drainage. There are two varieties: "loop enterostomy," when the opening is made into a coil without its division, and "terminal enterostomy," when the proximal open end is used after the bowel has been cut across. In this case the distal lumen must be closed by suture or fixed in the parietal incision, where it may be used for drainage or irrigation or subsequently closed Enterostomy may have to be employed when the patient is desperately ill from intestinal obstruction, with an enormously distended abdomen but without indication as to the site. In such conditions a blind loop enterostomy will overcome the immediate necessities and may assist in carrying the patient on to a stage at which a complete operation for the location and removal of the cause may be carried out. Lastly, an enterostomy of the lowest part of the ileum, usually of the terminal type (p. 1113), has been used as the most effectual way of resting the colon in extreme colitis. These measures are usually temporary, and when the opening has fulfilled its purpose it may heal spontaneously or must be closed by operative interference, such as excision and anastomosis for restoration of continuity. An opening into the small intestine for the purpose of feeding the patient is quite a different measure, carried out in the upper small bowel, and known as jejunostomy. The main disadvantage of the operation of enterostomy is that the opening may develop into an intestinal fistula which, if it happens to be high in the bowel, will cause so great a loss of intestinal contents as to lead to rapid starvation and death. Wherever situated, there is the risk of constant discharge of intestinal contents gravely interfering with nutrition and always causing troublesome local skin irritation. For these reasons it is most important to endeavour so to plan the operation that the purpose of draining the intestine can be carried out with the least chance of subsequent fistula.

Technique.—If there is no pre-existing incision which can be used, the abdomen should be opened in the right iliac fossa, for in this situation it is more likely that the lower part of the small intestine will be encountered. An incision only big enough to allow a distended coil of intestine to be withdrawn is required A rubber catheter, size No 12, is then fixed in the bowel after the method of Coffey. This operation is comparable with that surgeon's technique of implantation of the ureter into the bowel, the catheter in the enterostomy taking the place of the ureter A longitudinal incision 2½ to 3 inches in length is made along the summit of the loop and is carried through the muscular coats down to but not including the mucous membrane. The muscular coat retracts and the mucous membrane bulges into the incision. A small opening just large enough to allow the catheter to be passed into the lumen of the bowel is made at the lower end of the incision. At this point the catheter is fixed to the wall of the bowel with a stitch to guard against accidental withdrawal. If the aperture in the

mucous membrane is too large, a purse string may be so placed as to draw the edges up around the catheter. The latter is then laid along the incision in the sulcus provided and lies on the outer surface of the mucous membrane. The muscular and peritoneal coats are then drawn together over the catheter either by a series of interrupted sutures or a continuous stitch. If necessary one or two Lembert sutures draw the peritoneum more securely into position. The extremity of the catheter should be plugged and passed through a hole which will just contain it, in the great omentum so that the latter intervenes between the small intestine and the parietes. The catheter is then brought out through the parietal incision, and the bowel wall, with the omentum, is anchored to the parietes by one or two catgut stitches at the point where the catheter comes through the wound. In this way the intestinal contents can be drained on to the surface, the bowel can be irrigated, or fluids can be fed to the intestine. When the enterostomy is no longer required, but not sooner than a week after being made, the catheter may be withdrawn and in most instances the opening will close of its own accord, that is supposing the cause of the obstruction has been dealt with or has spontaneously disappeared. Before the plan of interposing the omentum between the intestine and the parietes was adopted, it was usual for the opening to remain patent so that the intestinal mucous membrane protruded on to the skin surface. In those circumstances a troublesome intestinal fistula resulted which could only be closed by operative interference. In spite of precautions this may occur and it is then necessary to separate the intestine from the parietes to expose the margins of the opening and to suture the aperture in a direction transverse to the axis of the gut. Sometimes the whole loop may have to be removed, a formal enterectomy being carried out. The skin irritation which often develops round the enterostomy may be relieved by painting with white of egg, or by a gauze dressing soaked in milk or by one of the aluminium pastes.

CHAPTER XX

ENTERECTOMY AND INTESTINAL ANASTOMOSIS

By G. GREY TURNER

THE indications for these procedures will be found in the appropriate article, and here it will be enough to describe the different methods by which the resection or anastomosis may be carried out.

In the early days of intestinal surgery the fear of leakage and the feeling that the suture-line required support led to the use of many contrivances, varying in complexity from Murphy's button to the absorbable bone bobbin. How much these mechanical contrivances assisted the progress of intestinal suturing, and how far they delayed the coming of anastomosis by simple suture, is a moot point. The day of these "aids" is over, but, nevertheless, intestinal surgery owes a deep debt of gratitude to their inventors, and particularly to J. B Murphy, of Chicago, whose ingenious button, with all its risks and disadvantages, made intestinal anastomosis an easy and even a relatively safe procedure and did a great deal to establish intestinal surgery in the comparatively satisfactory position which it now occupies.

At the present time intestinal anastomosis is invariably carried out by direct suture without mechanical supports of any kind. Various "machines" of great ingenuity have been invented to reduce the labour of suturing with ordinary needles manipulated by hand with or without the help of a holder These pieces of complicated apparatus have not yet become popular with surgeons in general and it can be stated with confidence that they are not essential, are limited in actual application, and lack the precision of the ordinary needle carefully and skilfully guided by a well-trained hand.

GENERAL CONSIDERATIONS

As the contents of the intestinal tract are contaminated with micro-organisms, no operation which involves opening the lumen can be performed strictly aseptically in spite of the very great help provided by the proper use of the sulpha group of antiseptics and the antibiotics. There is, therefore, in all intestinal operations some risk of failure due to infection. In dividing the intestine it is impossible to avoid soiling the future suture-line, and the passage of the needle in the "all-coats" suture carries infection, with a risk of ulceration healing by granulation, and subsequent stricture.

The Lembert suture reduces the risk of a leak to a minimum wherever there is a serous coat, but at the point where the leaves of the mesentery separate to enclose the bowel there is a space uncovered by serosa,

very narrow, it is true, in the small intestine, but wide in some parts of the ascending and descending colon. This area requires special care. The use of chemotherapy and the antibiotics has played a great part in the improvement in the results during the last years and deaths from peritonitis are now very unusual. The general morbidity has also steadily declined and the period of hospitalization has been shortened by about 20 per cent.

Preparation of patient. will vary with the condition demanding operation and obstruction must of course be treated with the minimum of delay. Whenever the condition allows the patient should be admitted to hospital for a period of four or five days so that a thorough investigation may be carried out. On actual preparation attention must be paid to the action of the bowels, the renal function, the respiratory and circulatory organs, the blood and the general nutrition. In order to diminish the hazards of infection, sulphaguanidine, sulphasuxidine, sulphathalidine or a similar preparation is given in divided doses over five days and is sometimes supplemented by streptomycin or terramycin used during the 48 hours immediately preceding operation. The diet must satisfy the body needs but must be of high caloric value and low residue. Intravenous fluids should only be used if indicated and this also applies to blood transfusion. Rest in bed is usually wise and is appreciated by the patient, but some do better if they are allowed up for a time each day. It should be remembered that it is possible to overdo preparation and that measures which are too irksome are not a good prelude to what may be a severe ordeal, mental as well as physical.

Technique.—Clamps are not essential but are convenient and make for cleaner and neater workmanship and also provide a convenient means of holding the bowel for necessary manipulation. The bowel should not, however, be injured by crushing and only light occluding clamps are permissible.

Suture material.—For many years the writer used nothing but fine chromicized catgut, and this proved entirely satisfactory ; size 3/0 is selected for the inner sutures and 3/0 or 6/0 for the outer layers. Silk or linen thread are quite reliable but, as they do not absorb, the inner suture, at all events, is probably always extruded into the lumen of the bowel by a process of ulceration and this may take a long time (Fig. 431). In the experimental animal silk is attended with minimal reaction but catgut has the advantage that, having served its purpose, it can be relied upon to absorb safely.

Needles should be rounded and of just such a size as comfortably to carry the suture material The eye-less atraumatic pattern is ideal but extravagant, and the accumulated experience of many years of successful intestinal surgery has shown that they are not essential.

So-called aseptic methods of anastomosis.—By the use of ingenious clamps or other forms of apparatus, attempts have been made to carry out intestinal anastomosis either without exposing the lumen

(Frazer and Dott) or with a minimum of exposure (Seton Pringle and Rankin)

In the writer's opinion these plans are founded on a misconception of the factors governing the results. If failure occurs, it is either due to intervention with the gut in an unsuitable condition as the result of obstruction, or to defective blood supply so that there is necrosis at the suture line, or it is due to careless application of the sutures None of these factors can be controlled by mechanical aids.

The principles which should guide the surgeon are : (1) Recognition that no intestinal anastomosis of any sort ought to be attempted in the presence of established obstruction. In this condition the bowel is distended and the wall is œdematous and probably infected and after any intervention is liable to paresis. When obstruction is incomplete, or in a very early stage, and the surgeon is tempted to do a complete operation rather than be content with preliminary drainage and a second stage resection, it is essential to provide a safety valve by previous short circuit or some type of temporary colostomy or enterostomy The conditions are different in acute strangulations where the blood supply is completely cut off from the bowel. Then the acute symptoms demand intervention before mechanical obstruction of the lumen of the bowel becomes an important factor and excision of large portions of intestine may be required. (2) It is essential that any operation which involves opening the bowel should be done only when it can be brought outside the abdomen In the small intestine there can scarcely ever be any difficulty, but in the large it is essential to secure this by mobilization. The recognition of this factor has been of great value in the development of the more successful operations for resection of the large bowel which are now usual (3) It is also important to see that the cut edge of the bowel is not flooded with intestinal contents during the application of the sutures, and for this reason it is the rule to use some type of restraining clamp This should be quite light and have a good spring in the blades so that they may attain their object while pressure on the wall of the bowel is reduced to a minimum Usually the

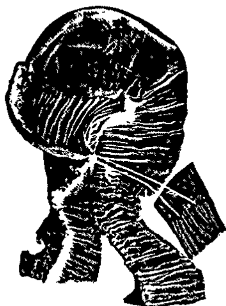


Fig. 431.—A linen-thread suture hanging loose in the intestine 8 months after its insertion at an operation for intestinal anastomosis.

(From G Grey Turner Macewen Memorial Lecture, 1939, Jackson, Son & Co , Glasgow)

blades are protected by rubber, but if the clamps are sufficiently light this is unnecessary. Except when it is necessary to crush the bowel to make a groove for an occluding suture, it is never wise to employ a heavy clamp. (4) Most cases in which failure of union occurs are due to some defect in the blood supply of the edges of the bowel at the site of the junction. This is so very important that the surgeon should not rely on pre-conceived ideas of what the blood supply should be, as indicated in textbooks of anatomy, but should satisfy himself by inspection and palpation of the mesentery that the blood-vessels are healthy and pulsating right up to the point chosen for the anastomosis. In order to be quite sure, it may be necessary to remove the clamps and wait for a few moments if necessary to actually see the bowel margin bleed freely. Occasionally the arrangement of the gauze packing or the kinking of the bowel over the edge of the abdominal incision is enough to account for some temporary interference with the vessels, and the surgeon must take care not to be misled in this way. (5) Further, there must be no tension and the bowel ends must lie snugly together without the least drag on the sutures. So far as the actual method of union is concerned, an anastomosis can always be made safely by simple suture in two layers, one continuous running stitch taking all the coats so as to make the union hæmostatic and watertight, and the second to bury the first by approximating the peritoneum Lembert fashion. At any point where the bowel is uncovered by peritoneum an attempt should be made to protect it further by the epiploic appendices, neighbouring fat or omentum. (6) If there is any doubt about the security of the anastomosis, it is essential that the bowel above it should be temporarily drained so that distension will not add an additional factor to strain the union. In these circumstances it is also wise to provide a track from the neighbourhood of the anastomosis through the parietal incision so that leakage can readily find its way to the surface and be less likely to give rise to peritonitis or local inflammatory trouble (7) If the patient has not had the advantage of a protective course of intestinal antiseptic drugs or antibiotics these should be administered and continued for several days after operation.

ENTERECTOMY AND END-TO-END OR AXIAL ANASTOMOSIS

Small intestine.—Having decided on the portion to be removed, the surgeon lifts the affected loop out of the abdomen with a sufficient length of healthy intestine on each side. (Fig. 432) The general cavity of the peritoneum is protected by large swabs wrung out of warm saline solution. The intestinal lumen above and below is controlled by applying light clamps, which do not perforate the mesentery, or by passing one end of a fine rubber tube through a hole in the mesentery, crossing the ends together over the gut firmly enough to occlude the lumen and retaining them with a pair of pressure forceps. At

the points selected for division of the intestine, an opening is made in the mesentery by blunt dissection as near the gut as possible, and these openings are enlarged as far towards the root of the mesentery as may be required. The mesentery on both sides of the proposed line of division is caught in a succession of artery forceps as the section proceeds. The actual division is most conveniently and cleanly made with scissors. In making this division it must be remembered that the mesentery is like an open fan, the attachment to the posterior abdominal wall being only about 6 in. long, while the intestinal attachment is about 22 ft. so that in all but very wide resections the incisions tend to meet at a point only a few inches from the edge of the bowel and enclose a triangular piece of mesentery.

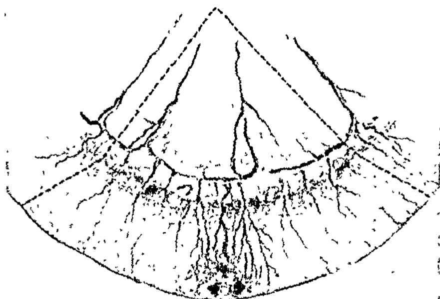


Fig 432.—Intestinal resection : line of division of gut and mesentery.

It is possible, when the mesentery is not loaded with fat, to start the incisions as near its root as the pathological condition demands and to make the section towards the gut. Or the division may be made more or less parallel with the portion of intestine to be removed if it is not essential to take away the lymph nodes. Whatever method is to be adopted, the mesentery should, if possible, be dealt with first in order to diminish the risk of infecting it from the bowel. The worst possible surgical fault is to divide the intestine and *continue into the mesentery with the same knife or scissors.* Sometimes it facilitates the operation to divide the bowel before the mesentery, and there can be no objection to this plan provided that fresh instruments are used for the mesentery and that the divided ends of the bowel are covered over with gauze swabs.

The vessels may either be caught by a series of encircling ligatures passed through the mesentery with a needle or forceps before its division, or, much more conveniently, sections may be taken up in a series of artery forceps and subsequently tied. It is not necessary to interlock the ligatures, nor are special clamps required for dealing with the mesentery. It is essential to use forceps whose blades meet along their whole length, otherwise portions of tissue are apt to elude their grasp and, in consequence, vessels retract and may be a source

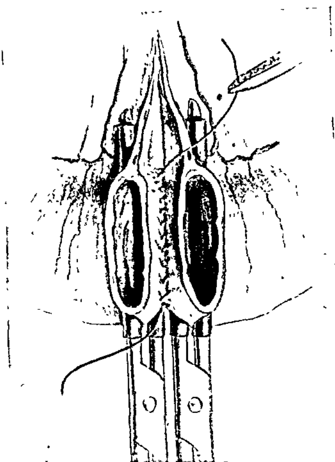


Fig. 433.—Intestinal anastomosis, end-to-end. Bowel ends held in apposition and posterior Lembert suture being applied.

of troublesome or even serious bleeding. In dealing with the fat mesentery it is important that an adequate amount of tissue should be left beyond the bite of the forceps, for it is in these cases that the vessels are especially apt to retract and escape the ligatures. If this accident happens, with formation of a spreading hæmatoma in the mesentery, extravasation rapidly occurs and must be dealt with at once. By far the best plan is to divide the mesentery over the hæmatoma in the course of the vessels and to squeeze away the extravasated blood so that the retracted and bleeding vessels can be seen and individually caught and tied.

The division of the mesentery having been completed, a large gauze swab is passed through the gap. The resection is then proceeded with, the intestine being divided cleanly with scissors slightly obliquely towards the mesentery. The open ends are wiped clean.

Nowadays practically every intestinal anastomosis is carried out by the method of simple suture in not less than two layers end to end. Light clamps are used and the bowel-ends held in apposition while the posterior peritoneal surfaces are secured by the Lembert stitch. (Fig. 433.) This is commenced at the antimesenteric border and is

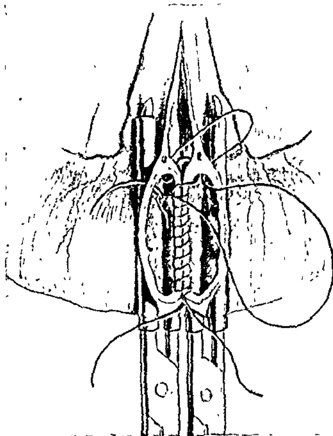


Fig. 434.—Intestinal anastomosis, end-to-end. The all-coats suture being applied.

continued across the whole distance of the bowel. After this posterior Lembert suture is completed, its end is left long with its needle, and is covered by gauze. The all-coats through-and-through suture is then commenced in the same way and is carried right round the bowel. In order not to absorb too much of the bowel-wall when the suture is tightened, it is wise to interrupt it at about three points by locking or actually tying the stitch and starting afresh. After the bowel has been encircled the posterior Lembert suture is carried round the front to the point where it was first commenced and is there tied to the end with which it started. (Figs 433–436.) Any point

where the apposition is not very accurate, or where there is an oozing area, may be supported and covered over by an additional interrupted Lembert stitch. The mesenteric angle where its leaves separate to enclose the bowel is undoubtedly a danger-point, but if great care is taken to see that the corresponding edge of the bowel is well inverted into the lumen by the all-coats stitch, no harm is likely to result. The carefully applied Lembert stitch further adds to this inversion and, passing continuously from the front to the back of the bowel,

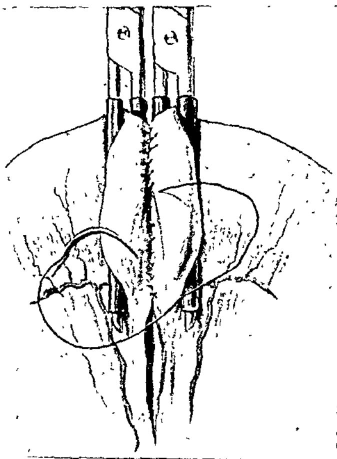


Fig. 435.—Intestinal anastomosis, end-to-end. The anterior Lembert suture.

tends to draw the mesenteric leaves together. The area is further supported by closing the gap in the mesentery. It is usual to leave the clamps in position until all the sutures have been inserted and tied, but they may be safely loosened at any time during the operation if (1) the surgeon is anxious to verify the adequacy of the blood supply, or (2) the clamps are too near the suture line and must be readjusted. They may be removed as soon as the inner all-coats suture has been applied, but they are convenient holders for the bowel and are usually left to the later stages.

The anastomosis is completed by uniting the divided edges of the

mesentery. In sewing together the mesentery there is a risk of pricking a vessel, and if this happens a hæmatoma forms between the leaves of the mesentery and may spread with great rapidity. To obviate this risk, Littlewood *suggested that opposing points of the mesentery should* be picked up with pressure forceps, and that these points should be tied together, and this is the method recommended. Most surgeons, taking the greatest care to avoid vessels, prefer joining the edges with a continuous suture, which excludes the risk of leaving even a small aperture.

If clamps are not used, the procedure is the same, but the sutures are more difficult to apply, owing to the mobility of the parts and the apparent surplus of mucosa. To meet the difficulty, it is usual to insert two guide sutures, one at the mesenteric, the other at the anti-mesenteric edge of the bowel, traction upon which will approximate *and steady the intestinal ends. These guide sutures should be* sero-muscular only, and may be removed as soon as the posterior sero-muscular suture has been applied. Whether or not clamps are used,

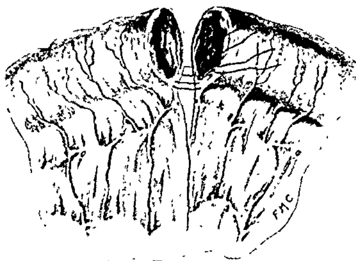


Fig. 436.—End-to-end anastomosis. Placing of mattress sutures across mesenteric angle as a first stage.

it is convenient to hold the bowel edges in contact by means of some type of *fine catch forceps These have been omitted from* the illustrations in order not to obscure the essential details. The method described is satisfactory and convenient, but the writer usually employs the technique which is used for anastomosis in the large bowel and is described and illustrated on pp. 1062–3. The posterior mattress sutures provide a good way of dealing with the mesenteric angle and can be relied upon to draw that part of the bowel into good apposition and ensure that the mucous membrane is safely turned towards the lumen. (Figs. 436–438.) Of course, the all-coats continuous and Lembert sutures are used in addition to bring the peritoneal surfaces into close apposition. In a few hours an exudative reaction produces a protective *seal between the parts.*

Some additional points.—The object of the continuous through-and-through all-coats suture is to make a water-tight union with control of the vessels. The stitch should be applied from the lumen of the bowel, for in this way the edges tend to be inverted and there should be little or no pouting of the mucous membrane on the outer surface. But to place this suture in this way is not essential, and some surgeons advise that the stitch should be an external overhand running suture. The *one* essential is to secure good hæmostasis with secure apposition but without narrowing the bowel at the site of the anastomosis. The distance between each needle puncture should not be more than a quarter of an inch, and the distance from the cut edge should be a little less. It is important that the suture should include the whole thickness of the bowel-wall. Sometimes the excess of mucous membrane makes the placing of the needle a little difficult, but the surgeon

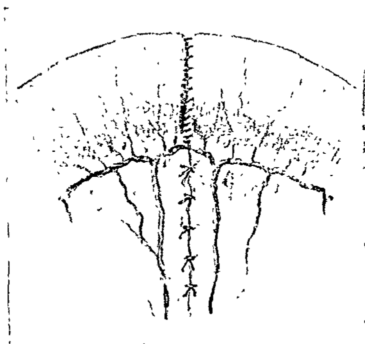


Fig. 437.—End-to-end anastomosis in small intestine completed, with gap in mesentery drawn together.

must *not* be tempted to cut mucous membrane away, as it is essential to have the submucous layer well protected by this excess. The Lembert sutures may be interrupted, though the small intestine lends itself to the continuous suture. When the latter has been completed there must be no hesitation in putting in an additional interrupted stitch here and there if pouting mucous membrane or oozing points indicate the need for additional protection.

Except in cases of injury where there is much bruising of the bowel, omental grafts are never necessary in small intestine suture. It is often stated that single layer suture is sufficient in the small bowel, but it is foolish *not* to adopt the additional safety that follows good

peritoneal apposition, which may be so readily secured by a Lembert suture, even if only inserted at a few points along the line of anastomosis. It is not necessary, nor indeed is it an advantage, to divide the bowel with the diathermy needle or the cautery or to attempt sterilization of the exposed mucous membrane In spite of the effective antibacterial therapy now available it is much better to regard the lumen

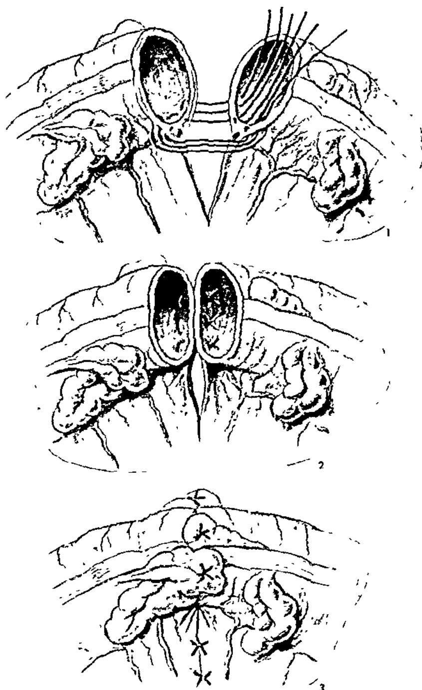


Fig. 438.—End-to-end anastomosis in the colon.

1. Approximation by posterior mattress-sutures. 2. The sutures tied, safely inverting the mesenteric margin. 3. *Anastomosis has been completed by insertion of the* all-coats and Lembert sutures The illustration shows the way the anastomosis is supported by stitching the neighbouring appendices over the suture line.

of the bowel as an infected area and to protect surrounding parts from contamination.

When the bowel wall is exceedingly thin, great care is necessary to avoid entering the lumen when placing the Lembert sutures. In these circumstances an adequate hold can often be best secured by passing the needle through the peritoneum parallel to the line of anastomosis.

Many problems in connection with end-to-end anastomosis have still to be made clear. We do not know how much of the gut wall may be infolded without risk of an immediate or late obstruction, nor whether a wide infolding gives a sounder suture line than otherwise. Halsted* said that the infolding of the wall may be great enough to

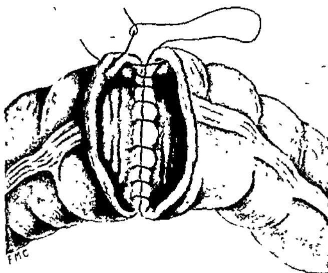


Fig. 439.—Continuous all-coats suture passed from the lumen of the bowel.

fill the lumen, and yet not cause obstruction. The fate of this diaphragm is doubtful. Does it persist, does it gradually or even rapidly unfold itself as the sutures absorb, or does it slowly shrivel or ulcerate away? An end-to-end anastomosis seen after a lapse of time does not show any diaphragm, nor is there a fibrous ring such as might be expected if the suture line healed by ulceration and granulation

End-to-end anastomosis in the colon.—Difficulties are said to occur owing to the thinness of the intestinal wall, its poor blood supply compared with the small intestine, and the presence of the appendices epiploicæ, which make a perfect sero-muscular suture line more difficult.

It is sometimes advised that the appendices should be removed from near the ends of the bowel before placing the sutures, but this is a mistake, for they are very useful as supports for the suture line and are also an additional source of blood supply. Their bases may be partially detached and extra fat may be dissected back from the suture line but should not be removed.

* *Journ Exper. Med*, 1912, xv, 216

End-to-end anastomosis is safest when the serous coat is complete, but at the same time, it can be done when a lateral anastomosis is impossible owing to want of material. A convenient and efficient plan is to begin by approximating the mesenteric side of the gut by a series of mattress sutures. (Fig. 438.) These turn the mesenteric part of the bowel well towards the lumen so that it can be safely taken up by the all-coats continuous stitch, which is next applied. This is commenced just to one side of the mattress-sutures and is continued across where they lie and then all round the bowel to finish off where it began. (Fig. 439.) It is wise to lock or even interrupt this suture at two places, but this presents no difficulty. The serous coats are best apposed by interrupted Lembert sutures, as a continuous stitch may interfere with the blood-vessels and the appendices. The bowel must be rotated so that the posterior sutures can be applied. Finally, the anastomosis is protected and strengthened by using the epiploic appendices as shown in Fig. 438. These must be fixed in position by a stitch here and there, but great care must be taken not to occlude the vessels in the appendices. If there is the slightest doubt about the integrity of the suture line or if the intestine is softened or friable from previous distension or infection, it is wise to bring a rubber tissue strand from the region of the anastomosis to the surface. In cases in which this is likely to be necessary the proper placing of the incision, as discussed later (Fig. 455, p. 1085), is very important. If the anastomosis is low down in the pelvic colon, a long tube may be passed from the anus well up beyond the anastomosis If this is not possible a tube should be left through the sphincter to prevent distension of the rectum

LATERAL OR SIDE-TO-SIDE ANASTOMOSIS

The supposed advantage over end-to-end anastomosis is that the *mesenteric angle is eliminated, so that the operation can be safely* performed even in parts of the intestine where the serous coat is not complete. It also allows union without difficulty between portions of bowel of different sizes. The disadvantages are that it takes a little longer, owing to the necessity of closing and over-sewing the open ends of the intestines to be anastomosed ; it requires a greater length of intestine ; and there is a tendency for the proximal blind end to enlarge *as the result of the vis a tergo.* As a step in short-circuiting, lateral anastomosis is an established procedure, and the indications will be considered in connection with intestinal exclusion After enterectomy, lateral anastomosis should be made isoperistaltic, not because it makes any noticeable difference in the passage of the intestinal contents, but the parts lie more naturally and the suturing is easier.

The choice of a point for the anastomosis must be decided by the purpose of the operation For instance, if the anastomosis is done after enterectomy it should be placed near the resection, so that the blind ends may be as short as possible. If done to short-circuit a

neoplasm, it must be placed at such a distance that it will not be likely to be invaded by the continued progress of the growth.

Technique of lateral anastomosis.—The resection of the portion to be removed is carried out as for axial anastomosis, and the two open

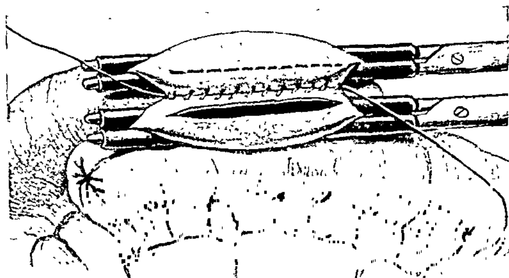


Fig. 440.—Intestinal anastomosis, lateral method : posterior sero-muscular suture inserted; one " cone " opened, *line of incision in the other indicated.*

ends are closed. In the small intestine this can be quickly and safely done by crushing the intestine at the point selected, tying a silk or strong catgut ligature around the gut at the site of crushing, and

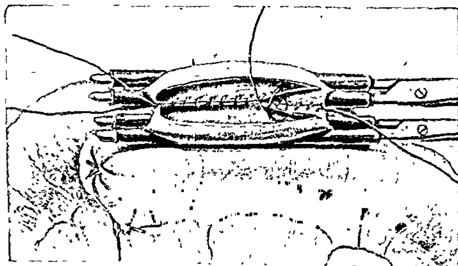


Fig. 441.—Intestinal anastomosis, lateral method : completing posterior all-coats suture.

cutting away the portion to be resected. The ligated ends are then inverted and buried under a sero-muscular purse-string suture, which may be safeguarded by a further superimposed purse-string, a mattress-stitch or one or two interrupted stitches. The colon may sometimes

be closed in the same way, but it is wiser to use a deliberate double row of sutures, the first all-coats, the second sero-muscular. The purse-string or continuous Lembert used to bury the ligated or sutured

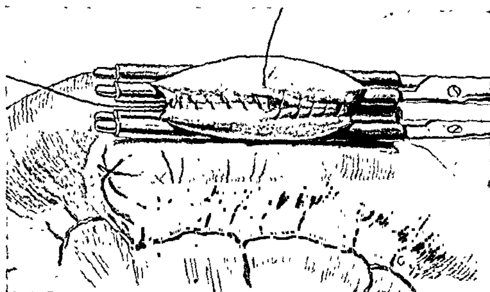


Fig. 442.—Intestinal anastomosis, lateral method : application of anterior sero-muscular suture.

bowel end must be passed at least half an inch from the area it is intended to invert. It should be possible to tuck in this area with the greatest ease. If it has to be forcibly inverted or the inverting

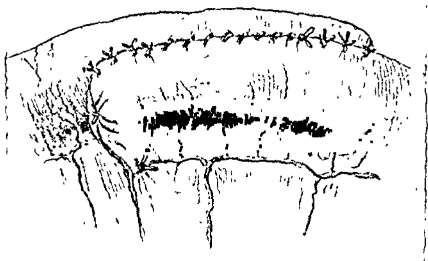


Fig. 443.—Intestinal anastomosis, lateral method : anastomosis completed.

stitch has to be drawn very tight then the proceeding cannot be regarded as satisfactory. The supposedly quicker but often more tricky methods of closing the ends which require special instruments

and technique are not recommended. One or other of the methods already described will fulfil all the indications. For the actual anastomosis, one-half the circumference of each section of the gut at its antimesenteric border is picked up and controlled by an intestinal clamp. The two surfaces to be anastomosed are then brought together, each held in its clamp, over a thick strip of gauze wrung out in hot saline solution, the clamps being held side by side or tied together at the blade-points and the hinges. Two large flat swabs wrung out in hot saline solution are placed one on each side of the clamps and meeting at each end, so that with the strip of gauze the area of operation is shut off completely from the cavity of the peritoneum. The apposed coats of the intestine are then sewn together by a continuous Lembert sero-muscular suture for a distance of about 2 in., the submucous coat being included. (Figs. 440–443.) This forms the posterior outer sero-muscular suture. An incision is then made parallel with and ¼ in. from the suture line through the serous and muscular coats of the two portions of intestine, so as to expose the submucosa. This is picked up with dissecting forceps and incised for the full length of the incision, thus opening the lumen of the intestine. It is not only unnecessary to excise an ellipse of mucous membrane but unwise, as an excess of the bowel lining covers and protects the more vulnerable sub-mucous layers. Doing this deliberately in two stages, i.e. exposing and then opening the mucosa, is of value in limiting soiling of the edges by the intestinal contents; any intestinal content is wiped away with small gauze pledgets.

Starting at the end farthest away, i.e. at the end at which the sero-muscular suture started, the contiguous cut edges are sewn together by an all-coats through-and-through continuous catgut suture (Fig. 441), which begins on the mucous surface of the right opening, and is therefore knotted on the mucosa. This suture joins the contiguous posterior intestinal walls together, and is knotted when the near end is reached. The anterior all-coats suture line is then carried out, the same thread being used, and the first stitch on the return journey being made by passing the needle from the mucosa of the left through all coats and crossing over to enter the right from without inwards. A simple overhand continuous suture may be used for this row, the greatest care being taken that each loop falls vertically along the suture line, or, if preferred, the "in-and-out" suture illustrated for end-to-end anastomosis may be employed. (Fig. 446.) When the far end is reached, the suture is knotted to the end left long at the commencement. The sero-muscular suture is then resumed (Fig. 442), the all-coats suture thus being buried under the continuous Lembert. When this reaches the far end it is knotted to the original end which was left long The clamps are removed and, after the gauze strip has been slipped away, the suture line is inspected and any bleeding-points controlled. Each blind end is then sewn to the proximal and distal portions of the anastomosed gut respectively, and the gap in the mesentery is closed by a few points of suture. (Fig. 443.)

be closed in the same way, but it is wiser to use a deliberate double row of sutures, the first all-coats, the second sero-muscular. The purse-string or continuous Lembert used to bury the ligated or sutured

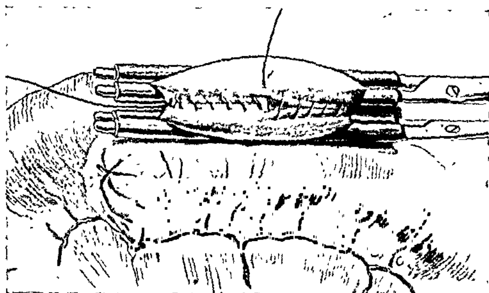


Fig. 442.—Intestinal anastomosis, lateral method : application of anterior sero-muscular suture.

bowel end must be passed at least half an inch from the area it is intended to invert. *It should be possible to tuck in this area with the greatest ease.* If it has to be forcibly inverted or the inverting

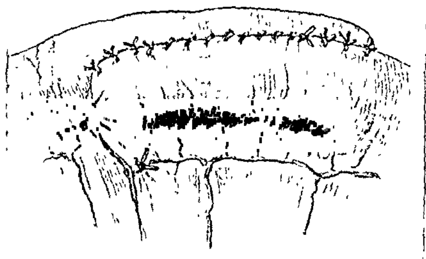


Fig. 443.—Intestinal anastomosis, lateral method : anastomosis completed.

stitch has to be drawn very tight then the proceeding cannot be regarded as satisfactory. The supposedly quicker but often more tricky methods of closing the ends which require special instruments

and technique are not recommended. One or other of the methods already described will fulfil all the indications. For the actual anastomosis, one-half the circumference of each section of the gut at its antimesenteric border is picked up and controlled by an intestinal clamp. The two surfaces to be anastomosed are then brought together, each held in its clamp, over a thick strip of gauze wrung out in hot saline solution, the clamps being held side by side or tied together at the blade-points and the hinges. Two large flat swabs wrung out in hot saline solution are placed one on each side of the clamps and meeting at each end, so that with the strip of gauze the area of operation is shut off completely from the cavity of the peritoneum. The apposed coats of the intestine are then sewn together by a continuous Lembert sero-muscular suture for a distance of about 2 in., the submucous coat *being included. (Figs. 440–443.) This forms* the posterior outer sero-muscular suture. An incision is then made parallel with and ¼ in. from the suture line through the serous and muscular coats of the two portions of intestine, so as to expose the submucosa. This is picked up with dissecting forceps and incised for the full length of the incision, thus opening the lumen of the intestine. It is not only unnecessary to excise an ellipse of mucous membrane but unwise, as an excess of the bowel lining covers and protects the more vulnerable sub-mucous layers. Doing this deliberately in two stages, i.e. exposing and then opening the mucosa, is of value in limiting soiling of the edges by the intestinal contents; any intestinal content is wiped away with small gauze pledgets.

Starting at the end farthest away, i.e. at the end at which the sero-muscular suture started, the contiguous cut edges are sewn together by an all-coats through-and-through continuous catgut suture (Fig. 441), which begins on the mucous surface of the right opening, and is therefore knotted on the mucosa. This suture joins the contiguous posterior intestinal walls together, and is knotted when the near end is reached. The anterior all-coats suture line is then carried out, the same thread being used, and the first stitch on the return journey being made by passing the needle from the mucosa of the left through all coats and crossing over to enter the right from without inwards. A simple overhand continuous suture may be used for this row, the greatest care being taken that each loop falls vertically along the suture line, or, if preferred, the "in-and-out" suture illustrated for end-to-end anastomosis may be employed. (Fig. 446.) When the far end is reached, the suture is knotted to the end left long at the commencement. The sero-muscular suture is then resumed (Fig. 442), the all-coats suture thus being buried under the continuous Lembert. When this reaches the far end it is knotted to the original end which was left long. The clamps are removed and, after the gauze strip has been slipped away, the suture line is inspected and any bleeding-points controlled. Each blind end is then sewn to the proximal and distal portions of the anastomosed gut respectively, and the gap in the mesentery is closed by a few points of suture. (Fig. 443.)

be closed in the same way, but it is wiser to use a deliberate double row of sutures, the first all-coats, the second sero-muscular. The purse-string or continuous Lembert used to bury the ligated or sutured

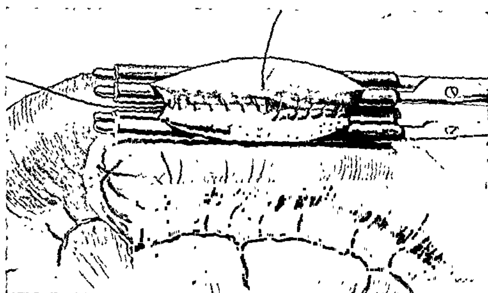


Fig. 442.—Intestinal anastomosis, lateral method : application of anterior sero-muscular suture.

bowel end must be passed at least half an inch from the area it is intended to invert. It should be possible to tuck in this area with the greatest ease. If it has to be forcibly inverted or the inverting

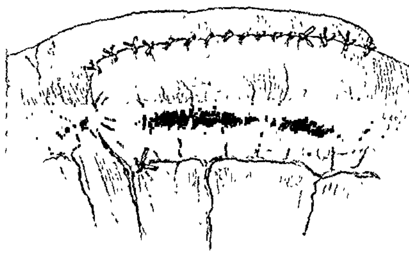


Fig. 443 —Intestinal anastomosis, lateral method : anastomosis completed.

stitch has to be drawn very tight then the proceeding cannot be regarded as satisfactory The supposedly quicker but often more tricky methods of closing the ends which require special instruments

Taking as a typical example the *ileo-transverse colostomy* after resection of the right colon, the ileum will have been divided distal to a clamp, and the open end of the transverse colon closed. The anastomosis is then made with the transverse colon at a point where the intestinal wall will hold a suture well, and where the intestines will lie snugly together. The posterior tænia is generally chosen, and is reached by raising the omentum and exposing the under-surface of the colon. A cone of the large bowel at the selected point, a couple of inches beyond the closed end, is lifted into and controlled by a clamp. The ileum is brought up and, by giving the clamp a quarter turn to the right, holding it in the right hand the open end is approximated to the colon and the serous surface is brought in contact with the selected portion of large bowel. The two surfaces are united for the length of the diameter of the ileum by a sero-muscular continuous Lembert suture (Fig. 444), the original knot-end being left long, and the suture again knotted at the end of the suture line and left with needle *in situ*.

The colon is then opened by an incision parallel with and ¼ in. from the suture line, and any contents of the open in- [illegible] together the apposed coats of the two bowels. (Fig. 445.) A simple running suture will do for this, the first knot and the loops being, of course, on the mucous surface. (Fig. 446.) The first (sero-muscular) suture is then resumed and the anterior Lembert finished, burying the all-coats suture line. (Fig. 447.)

The cut edge of the mesentery is carefully united to the mesentery of the colon. (Fig. 448.)

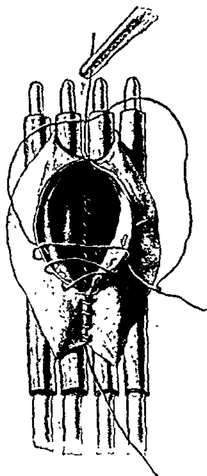


Fig. 446.—Illustrating the "in-and-out" all-coats suture, in anastomosis.

Side-to-end anastomosis.—This is another method of anastomosis which may be used in restoring continuity by ileo-transverse colostomy after resection of the right colon. It is said to have the advantage over end-to-side anastomosis that axial rotation is impossible, and that there is no risk of even temporary closure of the anastomotic opening as the result of œdema; and over lateral anastomosis, that there is only one blind end, and that a very short one, which tends to empty itself by force of gravity. The details of the operation do not differ from those already described for entero-anastomosis. (Fig. 449.)

With one portion overlapping the other, this gap in the mesentery is more potential than actual.

OTHER ANASTOMOSES

End-to-side anastomosis.—This method of restoring continuity is used occasionally in small-intestine anastomosis, as in the Moynihan-

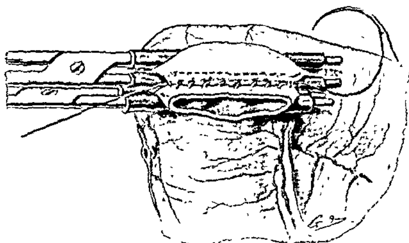


Fig. 444.—Intestinal anastomosis, end-to-side. The posterior sero-muscular suture is applied. Line of incision in colon shown.

Mayo retrocolic partial gastrectomy, or the old Roux's entero-enterostomy *en Y* after gastro-enterostomy. It is more often employed in anastomosing the small and large intestine, as in ileo-transverse

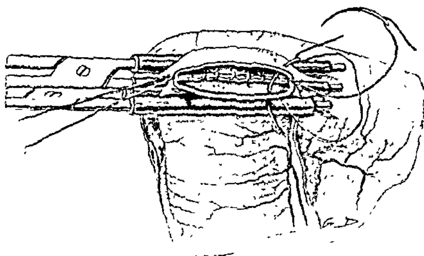


Fig. 445.—Intestinal anastomosis, end-to-side: beginning anterior all-coats running suture.

colostomy after resection of the right colon, or in ileo-sigmoidostomy. It is easily done, and does not often leak, but it has a theoretical disadvantage in the risk of axial rotation, though in practice that complication very seldom occurs.

Taking as a typical example the *ileo-transverse colostomy* after resection of the right colon, the ileum will have been divided distal to a clamp, and the open end of the transverse colon closed. The anastomosis is then made with the transverse colon at a point where the intestinal wall will hold a suture well, and where the intestines will lie snugly together. The posterior tænia is generally chosen, and is reached by raising the omentum and exposing the under-surface of the colon. A cone of the large bowel at the selected point, a couple of inches beyond the closed end, is lifted into and controlled by a clamp. The ileum is brought up and, by giving the clamp a quarter turn to the right, holding it in the right hand the open end is approximated to the colon and the serous surface is brought in contact with the selected portion of large bowel. The two surfaces are united for the length of the diameter of the ileum by a sero-muscular continuous Lembert suture (Fig. 444), the original knot-end being left long, and the suture again knotted at the end of the suture line and left with needle *in situ*.

The colon is then opened by an incision parallel with and ¼ in. from the suture line, and any contents of the open in- [illegible] together the apposed coats of the two bowels. (Fig. 445.) A simple running suture will do for this, the first knot and the loops being, of course, on the mucous surface. (Fig. 446.) The first (sero-muscular) suture is then resumed and the anterior Lembert finished, burying the all-coats suture line. (Fig. 447.)

The cut edge of the mesentery is carefully united to the mesentery of the colon. (Fig. 448.)

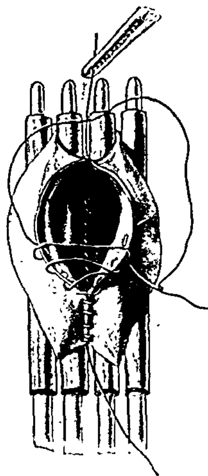


Fig. 446.—Illustrating the "in-and-out" all-coats suture, in anastomosis.

Side-to-end anastomosis.—This is another method of anastomosis which may be used in restoring continuity by ileo-transverse colostomy after resection of the right colon. It is said to have the advantage over end-to-side anastomosis that axial rotation is impossible, and that there is no risk of even temporary closure of the anastomotic opening as the result of œdema; and over lateral anastomosis, that there is only one blind end, and that a very short one, which tends to empty itself by force of gravity. The details of the operation do not differ from those already described for entero-anastomosis. (Fig. 449.)

Type of anastomosis.—End-to-end anastomosis is the most satisfactory and can nearly always be performed and the experienced surgeon rarely uses end-to-side, side-to-end or side-to-side junctions. [Professor Grey Turner almost invariably performed the end-to-end operation (L.C.R.).]

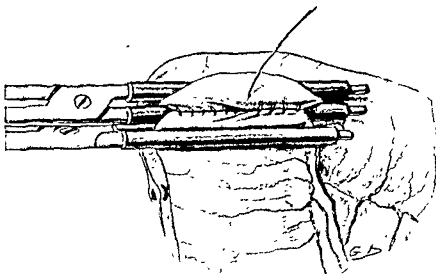


Fig 447.—Intestinal anastomosis, end-to-side : final suture, anterior sero-muscular.

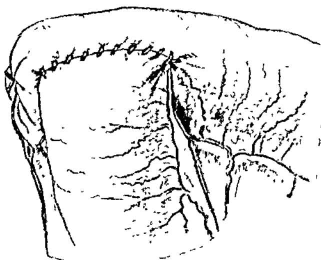


Fig. 448.—Intestinal anastomosis, end-to-side : anastomosis completed (Note the very short blind end.)

Anastomosis when the ends are of unequal size.—This is often the case when the small intestine has to be united to the colon. The situation may be met by resorting to lateral anastomosis or one of the methods of end-to-side union, but the surgeon may prefer the axial method with all its advantages. To enable this to be done the inequality may be overcome or much diminished by cutting the end

of the small intestine obliquely or making an incision along its antimesenteric border and trimming off the corners. When this does not completely suffice, further help can be obtained by modifying the application of the all-coats suture: (a) by taking a rather larger bite of the end with the bigger lumen, or (b) by taking two bites of this end to each one of the smaller end. Where the disparity is very great it may be overcome by diminishing the larger end by suture, using one of the methods represented in the diagrams. (Fig. 450.)



Fig. 449.—Intestinal anastomosis, side-to-end ileo-colostomy showing the ileum united to the transverse colon. The posterior parietal peritoneum and the omentum are also visible.

Temporary enterostomy combined with resection.—In the small intestine this must be avoided whenever possible. When it is felt at the time of operation that a safety valve must be provided, an enterostomy may be made about two feet above the site of anastomosis by the technique described on p. 1050. Measures to restore the tone and contractility of the distended small bowel and the use of the principle of decompression are essential.

INTESTINAL EXCLUSION

The intestine is said to be " excluded " when the normal course of flow of the contents is diverted. Exclusion may be partial or complete. For instance, if a lateral anastomosis be made between two portions of intestine on either side of an obstruction, the exclusion is only partial, and is generally called a " short circuit ". If, again, the gut is cut across above and below the obstruction, the part included between the two cuts is " completely excluded ". Or if the gut above an obstruction is divided across and the proximal end anastomosed to the intestine below the obstruction, then a condition results which is called " complete unilateral exclusion ". So that exclusion may be described as (1) bilateral partial, or short-circuiting; (2) unilateral complete, and (3) bilateral complete.

Indications.—One or other form of exclusion has been employed in many conditions, either as a permanent treatment or as a first step in a two-stage enterectomy. Of these conditions the chief are *obstructions* of various kinds, e.g. that due to regional ileitis (Crohn's disease) and *fæcal fistulæ*. Short-circuiting has a definite value in acute obstruction, e.g. in mass obstruction by bands (*see* p. 1017), and very occasionally in paralytic ileus when the other means now available are not successful and in which the importance of avoiding a fistula high up in the jejunum is obvious. In organic obstruction of the colon,

e.g. in malignant disease, an anastomosis may be done between the small intestine and the colon beyond the stricture (especially valuable in stricture of the ileo-cæcal valve or cæcum), or between colon and colon, e.g. transverse to sigmoid in splenic-flexure growths, or cæcum

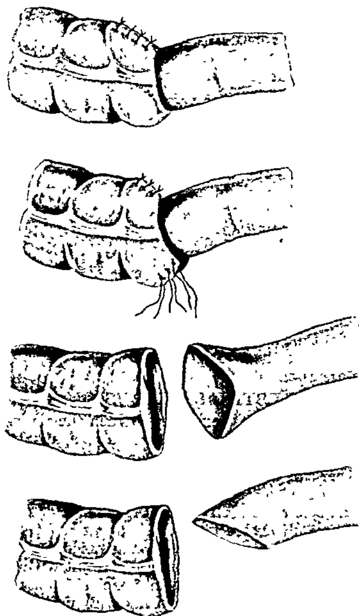


Fig. 450.—Methods that may be used when the bowel ends are of unequal size. For the sake of clearness most of the sutures are not shown.

to sigmoid in transverse-colon growths It is, however, in these operations for colonic obstruction that difficulties arise, and it is well to have certain definite rules which can be applied to the various conditions met with, especially as many of these operations are done in emergencies as a temporary measure to relieve obstruction before a radical operation can be attempted

Difficulties and contra-indications.—In operating for *fæcal fistula* it is important to remember that a simple short circuit is useless, and that, owing to reverse peristalsis, a unilateral complete exclusion may also prove ineffective. For instance, suppose it be desirable to close

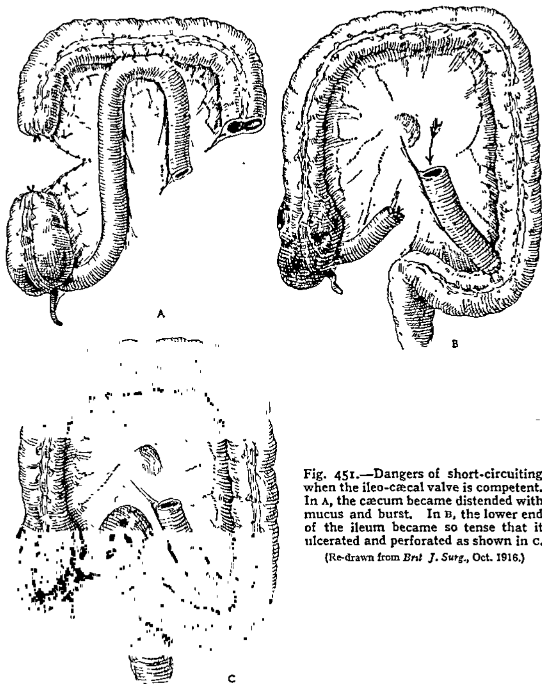


Fig. 451.—Dangers of short-circuiting when the ileo-cæcal valve is competent. In A, the cæcum became distended with mucus and burst. In B, the lower end of the ileum became so tense that it ulcerated and perforated as shown in C.
(Re-drawn from *Brit J. Surg.*, Oct. 1916.)

a fæcal fistula *in the cæcum which has occurred either* as the result of gangrenous appendicitis or following a deliberate artificial anus for a temporary obstruction, and that all attempts at closure by local operations have failed. It is quite useless to do an ileo-colostomy or an ileo-sigmoidostomy, whether a lateral anastomosis or an anastomosis

after division of the ileum be chosen. In the former the intestinal flow is only partly diverted, and in the latter reverse peristalsis will bring fæcal matter in the direction of the fistula, which will continue to discharge, though of course to a lesser degree.

Bilateral complete exclusion is necessary for cure: that is division of the ileum close to the ileo-cæcal valve, a division of the colon beyond the fistula, and subsequent removal of the excluded intestine. If the latter step is not considered wise, the fistula must remain open

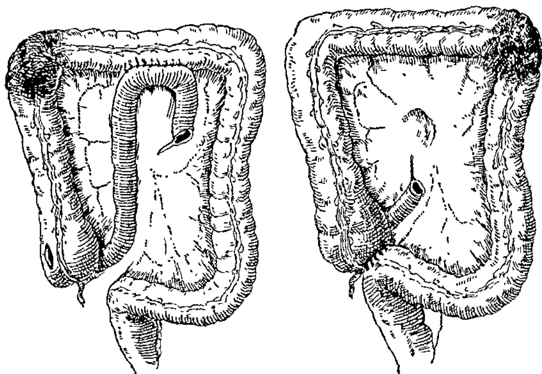


Fig. 452.—Methods of short-circuiting devised to guard against the complications illustrated in Fig. 451.
(Re-drawn from *Brit Journ Surg*, Oct. 1916.)

to some extent to allow the escape of mucus, which is constantly secreted and may lead to rupture of the cæcum unless an exit is provided. (Fig. 451, A.)

In choosing a site for the anastomosis to restore continuity, a point of special importance is to avoid *long blind ends.* In, for example, a growth of the right colon causing obstruction, but amenable later on to radical block-resection, the anastomosis of the preliminary exclusion operation must be so placed that a long blind end will not be left after the radical operation. In such a case an ileo-sigmoidostomy must not be chosen, as that would mean that the block-resection would leave a blind end consisting of half the transverse colon and the descending colon, which would be kept constantly full of fæcal material by reverse peristalsis. This reverse peristalsis is the great disadvantage of ileo-sigmoidostomy (end-to-side unilateral complete exclusion) for colonic stasis. In the majority of cases, soon after the operation, a

mass forms in the right iliac fossa composed of the cæcum filled with inspissated fæces, and the discomfort sometimes makes a subsequent colectomy imperative.

Again, in an instance of an inoperable colonic obstruction, e.g. advanced cancer in the cæcum or at the ileo-cæcal valve, the operation of complete unilateral exclusion is sound, but if the growth is at the hepatic flexure a similar procedure is unsound, as with complete obstruction of the colon due to advancing growth the cæcum and stump of the ileum may become so distended with mucus that it may eventually give way. (Fig. 451, B.)

The same is true of a splenic-flexure growth, when an ileo-sigmoidostomy is unsound, as the right colon and transverse colon are undrained.

Attempts have been made to overcome this difficulty by anastomosis between the cæcum and iliac colon (Giordano-Bergmann), but this leaves two long culs-de-sac, which again is essentially unsound.

It seems quite clear that if it is impossible to avoid the formation of a cul-de-sac, it should be drained by a fistula made at its extremity. This is automatically ensured in the case of a fæcal fistula, which acts as a vent for the small quantity of fluid excreted by the mucosa of the excluded intestine. In other cases a deliberate independent small cæcostomy must be made.*

Another danger arises in connexion with lateral anastomosis even if resection is carried out. Should the proximal blind end be too long, there is a tendency for it to become permanently filled and to enlarge and become inflamed and ulcerated, and cases have been recorded where this end has given way and caused peritonitis. Unfortunately the intestinal contents pass to the end of the proximal cul-de-sac and overflow through the stoma afterwards, so that this tendency of the proximal cul-de-sac to " balloon " is understandable. The late Mr. Carson used to quote the case of a patient, suffering from fæcal fistula after gangrenous appendicitis, for whom he carried out ileo-transverse colostomy side-to-side, with subsequent removal of the excluded colon but with rather a long blind end. Two years and three months later the woman fell downstairs, and was immediately seized with generalized abdominal pain. The abdomen was opened, and it was found that the distended proximal cul-de-sac had ruptured with considerable extravasation.

When ileo-transverse anastomosis has been made as a first step in a two-stage removal of the right half of the colon, blind ends may be avoided by making an end-to-end anastomosis, i.e. divided ileum to divided distal colon, at the time of the excision (Dorling). Of course, this can only be done when there is a sufficiency of bowel to admit easy approximation of the remaining ends after a sufficiently wide resection. When these conditions obtain, this end-to-end anastomosis is a convenient method of completing the operation, and is easier and safer than tucking in two blind ends. The ileo-transverse colostomy is not interfered with.

* Grey Turner, *Brit Journ. Surg*, Oct. 1916, iv, 227.

CHAPTER XXI

OPERATIONS FOR CANCER AND OTHER CONDITIONS OF THE LARGE INTESTINE

By the late G. GREY TURNER

EXCLUDING malignant disease of the rectum, *which comprises nearly* ... nd is considered under a ... be affected, though a very ... *pelvic portions. Thus, in* a series of 142 consecutive cases, cancer occurred in the following situations:—

Pelvic and iliac colon	69 times or 48·6%
Descending colon	9 ,, ,, 6·3%
Splenic flexure	15 ,, ,, 10·5%
Transverse colon	14 ,, ,, 9·9%
Ascending colon and hepatic flexure	13 ,, ,, 9·1%
Cæcum	22 ,, ,, 15·5%

These figures though dealing with a small series are fairly representative of the incidence and site of large bowel growths. In a series of 331 growths Cuthbert Dukes* found that the lesion was three and a half *times more frequent in the left colon than in the right.*

Types of growth.—The majority of colon growths are columnar-celled carcinomata. There is comparatively little tendency to lymphatic spread, and distant metastases are unusual. But it is a great mistake to assume that all cases have the same degree of malignancy. Some, probably a third of the total number, disseminate widely and, *it may be, before the primary bowel growth has produced marked* symptoms.

Growths at the splenic flexure sho ... than cæcal or ascending-colon growths, ... rhous type. Growths of the cæcum and ... en of the massive ulcerating type, and rarely give rise to obstruction. Scirrhous growths are much more common in the left than in the right colon, and so obscure are the symptoms in the early stage that it is estimated that in 40–60 per cent. obstruction is the first sign of the disease. It is this factor that is usually blamed for the comparatively high operative mortality, and the decision as to the scope of the operative treatment primarily depends on whether obstruction is or is not present.

The gross anatomical features of these growths are as important as their microscopic structure. Four definite varieties may be recognized: the massive growth forming a tubular stricture, *the infiltrating ulcer*

* *Proc Roy Soc Med.*, Feb 7th, 1945, Vol 38

limited to a segment of the wall of the bowel, the constricting type or "ring carcinoma", and the "cauliflower" or papillomatous variety. The massive type is the most common up to the splenic flexure, and beyond that the constricting variety. The papillomatous type is not so common as in the rectum and is usually only found in the lower part of the great bowel. The recognition of the gross anatomical structure of these growths has already proved to be valuable in assessing the prognosis of those in the rectum (Cuthbert Dukes). The papillomatous variety is the least malignant, whereas the ulcerative type, which

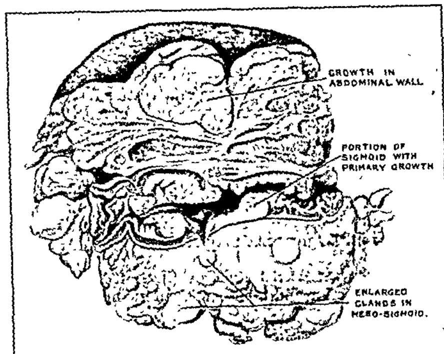


Fig. 453.—Carcinoma of the sigmoid involving a large area of the abdominal wall. Excision with end-to-end anastomosis. The patient was alive and free from recurrence twelve years later.

from the first exhibits infiltrating properties invading the bowel-wall deeply, is the most malignant. In the former variety glandular involvement is infrequent and late, whereas in the latter it is not only early but apt to be widespread. When the growth is on the mesenteric side of the bowel the prognosis is unfavourable. But these distinctions have more to do with prognosis than with treatment and do not in any way alter the general truth that growths of the large bowel are not usually particularly malignant and, despite extensive local involvement, yield very good results when thoroughly removed.* The surgeon must therefore not be easily deterred, and unless there is evidence of distant dissemination or of widespread deposits in the peritoneum there are few cases in which the radical operation cannot be carried out with fair prospect of ultimate success. But such an operation may have to be very extensive, as for instance when the growth directly

* That is in comparison with malignant disease in other parts of the alimentary canal.

involves neighbouring structures. There are many successful cases on record where growths invading the abdominal wall *or the viscera, e.g.* the pelvic contents in women, adjoining loops of small intestine, or part of the stomach, the spleen or the kidney, or a portion of the liver, have been successfully removed not only with immediate recovery but with freedom from recurrence for several years. (Figs. 453, 466.) In dealing with malignant disease of the large bowel there can be no doubt that the thorough local removal is more important than any extension to remove the whole area of lymphatic drainage. Fortunately, in many parts of the large bowel it is anatomically possible and comparatively easy to carry out an ideal operation for malignant disease, and this is particularly so with the right half of the colon. Many of the lymph nodes found enlarged in these cases are not infiltrated with growth, but are inflammatory, the result of absorption from ulcerated surfaces. While this forms no excuse for leaving nodes that are obviously enlarged, it is nevertheless an encouraging feature. The amount of healthy bowel to be removed on either side of the growth is a matter of great importance. The spread of bowel cancer does not appear to be by submucous lymphatic permeation, and while it is desirable to remove a sufficient area, it must not be supposed that this necessarily means an extravagant resection in every case. Probably 4–5 in. above and 2–3 in. below the obvious growth is a sufficient margin of safety in the great majority of cases.

Surgical anatomy. Arterial supply. (Fig. 454.)—The colon is supplied by the superior and inferior mesenteric arteries through the following branches:

From the superior mesenteric.—By the *ileo-colic*, which supplies the last 7 or 8 in. of the ileum, the cæcum, appendix, and part of the ascenc ... ove with the vasa intestina tenuis and b ...

By ... the ascending colon, anastomosing above ... vith the middle colic.

By the *middle colic*, which supplies the transverse colon, anastomosing at the hepatic flexure with the right colic and at the splenic flexure with the left colic.

From the inferior mesenteric.—By the *left colic*, which supplies the descending colon, anastomosing at the splenic flexure with the middle colic, and below with the ascending branch of the highest sigmoid artery.

By the *sigmoid arteries*, which supply the iliac and pelvic colon, anastomosing above with the descending branch of the left colic and below with the superior hæmorrhoidal. The anastomosis with the superior hæmorrhoidal is very variable, and this has been called by Sudek the "critical point". De Dietrichs, quoted by Hartmann,* says that if the inferior mesenteric is ligatured above the last sigmoid branch, circulation is maintained, but if below the last sigmoid branch,

* *Ann Surg*, 1909, *l*, 1091.

gangrene of the rectum follows. Pauchet (*loc. cit.*) says that if the inferior sigmoid artery and the superior hæmorrhoidal are tied separately, the circulation in the marginal artery (a term he applies to the anastomosis by arcades) is destroyed, and gangrene results. If, on the contrary, the ligature is applied to the trunk of the inferior mesenteric at a point above the last sigmoid artery, circulation will be

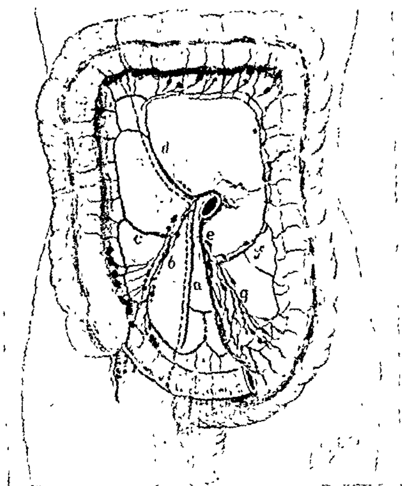


Fig. 454.—Diagram of blood-vessels and lymphatic glands of colon, with shaded area to show part removed in growths of right colon.

a, Superior mesenteric artery; *b*, ileo colic artery, *c*, right colic artery; *d*, middle colic artery, *e*, inferior mesenteric artery; *f*, left colic artery, *g*, sigmoid branches.

maintained, even in the superior hæmorrhoidal artery. If, he adds, the marginal artery is preserved, the middle colic artery can nourish the descending colon and sigmoid, even if the inferior mesenteric artery is tied at its origin. In actual practice the surgeon should determine by direct inspection and palpation whether or not the blood supply is adequate at the point at which anastomosis is to be made.

Lymphatic distribution.—Our knowledge of the lymphatic vessels and lymph nodes draining the colon is due to the researches of Jamieson and Dobson.* They describe four groups of glands—(1) the *epicolic* on

* *Ann. Surg.*, 1909, *l*, 1077.

the intestinal wall; (2) the *paracolic* on the arterial arcades; (3) the *intermediate* along the main arterial supply, and (4) the *main group* round the arteries at their origin. In a series of diagrams they represent the scope of an operation necessary to remove a colonic growth in various situations with its lymphatic area, bearing in mind the arterial distribution. Thus, for growths of *cæcum and ascending colon*, the ileo-colic branch of the superior mesenteric artery must be tied at its origin, and all the intestine supplied by it removed, with its mesentery and lymphatic distribution. This involves removal of the last 6 in. or so of the ileum, the cæcum, ascending colon, and hepatic flexure.

For growths of the *hepatic flexure*, the parts supplied by the middle colic artery must be removed, and as this devitalizes a large part of the ascending colon, especially when the right colic artery arises from the middle colic, the upper section should be through the ileum at the same point as for cæcum and ascending-colon growths.

For *transverse-colon* growths, only the paracolic glands need be removed with the colon, which must be resected 3–4 in. on each side of the growth.

For growths of the *splenic flexure*, all the bowel supplied by the left colic artery, and its associated lymphatic area, must be removed, i.e. the colon from the junction of the middle and left third of the transverse colon to the middle of the descending colon.

For growths in the *descending colon* the same point is taken on the transverse colon, while below, the colon is divided at the middle of the sigmoid flexure, supplied by the upper sigmoid artery.

For growths in the *sigmoid flexure*, the point of origin of the left colic artery is the limit for lymphatic removal.

These are, of course, ideal resections, and it may be well to remember that growths of the left colon tend to the scirrhous type, with comparatively limited lymphatic involvement.

Direct invasion of the veins is not usual and is much less than that found in rectal growths.

EXCISION OF GROWTH

Excision of a malignant growth is the operation most often required in the surgery of the large bowel. Since the earlier stages of its development, half a century ago, a great many different methods have been evolved. Most of these concern matters of detail but some involve important principles. At the present time it is generally agreed that no attempt at excision should be made in the presence of obstruction, which must first be dealt with by drainage of the bowel or short-circuiting. In the absence of obstruction or when this has been successfully overcome the methods available are:—

(1) Intra-peritoneal excision, with immediate restoration of continuity by direct anastomosis.

(2) Preliminary drainage of the bowel by cæcostomy or colostomy,

followed after an interval of two or three weeks by intraperitoneal excision and restoration of continuity by anastomosis. As a last step, a further operation for the closure of the colostomy is usually required. This is the typical multiple-stage operation.

(3) Preliminary defunction of the portion of bowel containing the growth. This is brought about by making a colostomy with the two ends so far separated that there is not likely to be contamination from one to the other. In this way the loop containing the growth is completely isolated and can be treated by irrigations, etc., with the object of reducing its infectivity to a minimum. After a time the growth is resected and continuity restored. As a final stage the colostomy is repaired. This is the method of Sir Hugh Devine.

(4) With or without preliminary bowel drainage, the portion of bowel containing the growth is mobilized and brought outside the abdomen, and is then excised. The bowel ends are stitched side by side so that they resemble a double barrelled gun, and are then fixed in the wound. Continuity is later restored by destroying the spur, though sometimes a further intervention is necessary to complete the closure. This is the method known by the name of Paul of this country and Mickulicz of Germany.

Many modifications have been introduced in each of these methods. While the general propositions involved still hold good the results have greatly improved since the better appreciation of the importance of adequate pre-operative preparation, the use of chemotherapy and the antibiotics and more studied after-care.

General Considerations

The frequent association of obstruction with colonic growths influences their management so much that it will be easier to consider the operative treatment under two heads—(1) in the absence of obstruction, and (2) when obstruction is present. It is accepted generally that in the presence of obstruction the duty of the surgeon is to relieve it and do nothing more at a first intervention. No operation for the radical removal is justifiable in the presence of obstruction whether complete or partial. In the writer's practice the operation in two stages exactly halved the mortality.

If the abdomen is distended and tense and the patient is vomiting, it is certainly unwise to carry out any exploration. In these circumstances a blind cæcostomy probably provides the maximum advantage. But it must be borne in mind that this operation cannot do more than relieve the distension of the bowel proximal to the growth and provide for the escape of intestinal contents. It does not ensure that the bowel will be completely emptied, or that it will recover its normal size and condition. If the growth is some distance away from the cæcum it

will be necessary to prepare the bowel by careful and repeated irrigation before any further operation, otherwise it will be found to be distended, thickened and œdematous, while it may also be ulcerated. For these reasons many surgeons advocate a transverse colostomy. If the obstruction is of a lesser degree and the abdomen is only slightly distended or merely full, while at the same time the condition of the patient will not allow the necessary careful examination by opaque enema, etc., much help may be obtained from plain skiagrams of the abdomen. In spite of all aids it may be necessary and feasible to open the abdomen for the purpose of exploration.

Exploration.—This can seldom be adequate through an incision which will merely admit the greased hand, as is sometimes advised. The object of the exploration is to determine the presence or otherwise of secondary deposits in the liver, the condition of the lymph nodes, and whether there are such extensions of the growth to neighbouring parts as to render an attempt at removal inadvisable.

The examination of the liver can be conducted blindly by palpation, but the relation of the growth to the surrounding parts can only be determined accurately under the guidance of the eye. If the surgeon has no hint of the location of the neoplasm, the incision should be in the mid-line below the umbilicus. The presence of a growth having been verified, the liver should next be examined. If palpation of the edge or the under surface gives definite information of secondary deposits, the upper surface should not be explored, because passage of a hand between the liver and the diaphragm certainly increases the risk of pulmonary complications Angiomata, adenomata and calcified scars and, in some parts of the world, small hydatids may all simulate secondary deposits of new growth. A multiplicity of nodules of not less than half an inch in diameter with umbilicated depressions about their centres is characteristic of metastatic growths. If deposits are found the question arises whether anything radical should be done. In the presence of multiple nodules it may add to the comfort of the patient to excise the primary growth especially if continuity of the bowel can be preserved by anastomosis. Generally nothing but steps to correct or to anticipate obstruction by a lateral anastomosis or by colostomy are justifiable.

To determine the significance of enlargement of the lymph nodes and the degree of local extension, it may be necessary to enlarge the incision, to use retractors and often to employ the Trendelenburg posture. It may be very difficult to decide whether the condition is neoplastic or inflammatory. Sometimes a lymph node may be easily removed for microscopic examination but, unless this yields a positive report of malignancy, it may be deceptive, for very often malignant lesions are associated with enlarged nodes which are only inflammatory. It is not wise to attempt to remove a piece of the mass in the bowel for biopsy because the little wound may not heal and peritonitis may result. Nodules of growth on the peritoneum are of much worse prognostic significance than quite extensive direct

involvement of viscera, parts of which can be removed with the growth. But whatever the condition found, at the back of the surgeon's mind should always be the admonition not to be easily deterred.

This exploration may be followed either by a colostomy at the most convenient spot in relation to the growth or by a preliminary anastomosis. The abdomen ought then to be closed and, with the certain knowledge which such an exploration has furnished, subsequent intervention for removal of the growth can be carried out with great precision.

Where there is no question of an acute or subacute obstruction the operation may be carried out in one stage. In these circumstances the surgeon must use his own judgment whether a temporary cæcostomy should be made as a last step in the operation to provide against distension of the bowel following the intervention. If there has been recent obstruction, or if the proximal bowel is at all distended, or if it contains much fæces, or if the operator has any reason to doubt the accuracy of the anastomosis, then it is much wiser to make a small cæcostomy which may close spontaneously after it has served its purpose. But it must be emphasized that this type of cæcostomy is never so satisfactory as one made as a deliberate preliminary a week or two previously. It always takes a few days for bowel drainage to become well established and until that takes place the advantage of the cæcostomy is doubtful. Fatal cellulitis of the abdominal wall, originating at the site of a cæcostomy made at the end of a long operation, has marred an otherwise satisfactory resection. If the resection is in the sigmoid it is also important to leave a tube in the rectum to guard against distension with flatus and to allow the escape of fæcal débris and mucus.

Preparation.*—In cases where obstruction is absent or has been relieved by drainage, there is time for adequate preparation before undertaking removal of the growth. For this purpose the patient should be admitted to hospital for not less than five days before operation. The most important points are emptying the bowel; when there is no obstruction, mild aperients such as cascara, mild saline cathartics or confection of sulphur and senna and liquid paraffin are valuable, while the bowel below the growth is emptied by moderate enemata and irrigated with saline solutions. Where there is no opening into the bowel above the growth, enemata must be used cautiously, for it may be easier for a copious injection to find its way through the growth into the bowel above than to return safely, and sometimes an attack of obstruction has been precipitated in this way. For 12 hours before operation the bowel should be rested, all medicines and irrigations being discontinued and 10 minims of tinctura opii given twice during this time. There is no one intestinal antiseptic which can be relied upon to sterilize the contents of the bowel but great improvement in diminution of infection has followed the use of chemotherapy and the antibiotics. At the present time sulphasuxidine,

* See also p. 1054

sulphaguanidine or sulphathalidine are usually employed. Any of these drugs may be supplemented by streptomycin. It is also important to prepare the whole intestinal canal by careful selection and limitation of diet. In principle, those foods which are known to leave a considerable residue or to cause gaseous distension should be avoided. At the same time the patient must have a sufficient diet, such as may be made up from soups, eggs, arrowroot or ground rice with cream, sugar, fruit juices and dry biscuits, and plenty of harmless liquid. The use of vitamins is important and especially vitamin C. During this probationary period the patient should not necessarily be confined to bed. The principle is to attain the maximum of healthy resistance with the least abdominal distension, and this may be promoted by moderate exercise. Stimulants and tobacco must be strictly limited. Anæmic patients should be treated, and if anæmia is well marked preliminary blood-transfusion is invaluable.

It is well to give liquid paraffin for a few days before operation and this may be helpful in convalescence. In two-stage operations the preparation is carried out before the resection, especial care being taken to empty the bowel below the colostomy and to remove any residue by irrigation. This latter procedure must, however, not be undertaken too frequently.

Technique.—In very ill patients, especially when there is vomiting, preliminary cæcostomy or colostomy may be carried out with the help of local anæsthesia but for exploration and for removal of the growths general anæsthesia is far the best. The most important points are to secure adequate exposure by suitably placed incisions and to effect thorough mobilization so as to ensure complete removal and to enable union to be made without tension. Whenever the growth is fixed by adhesions or by invasion of the surrounding structures, the incision should be made directly over it, or if a median or paramedian incision has been made the surgeon should not hesitate to make a separate independent incision over the growth or to add a transverse incision to his original one. (Fig. 455.)

The proper mobilization of these growths converts many a hopeless-looking case into a promising one, but it must be done under direct vision, and for this reason the exposure by incisions directly over the affected area is very valuable.

When the fixity is due to peritoneal adhesions, they are often an exaggeration of those bands and membranes which are so common in connection with the large bowel. These can always be dealt with by free use of the scissors, but there is often a good deal of bleeding which must not be neglected. If, on the other hand, the fixation is due to actual infiltration of surrounding parts by the growth, the problem of its removal can only be settled under the guidance of the eye. In the absence of distant dissemination the surgeon must not be easily deterred* and there is no excuse for timidity.

* See "Medical Society Oration on Cancer of Colon," Grey Turner, *Lancet*, May 18 and 25, 1929, i, 1017 and 1073.

In the actual removal of the growth it is usually best to divide the bowel at one or other extremity of the part to be resected, usually the distal end, and to approach the mesentery in this way. The vessels may be ligated before being divided or the mesentery may be clamped in sections on both sides of the proposed division and then ligated off, section by section, after the removal is complete. This is the best method provided the " bites " are not too bulky. The position of the main vessels if not easily seen may be demonstrated by trans-illumination but this is not of much practical value.

The technique of the anastomosis is dealt with in the previous section, but of course it admits of much variation in detail. The essentials for success are to ensure that the parts have an adequate blood supply ; that they can be made to lie in apposition without tension ; and that the edges to be sutured are not damaged by crushing clamp or cautery. Every anastomosis of the large bowel should be protected by neighbouring appendices or omentum or loose tissue tacked over the outer suture line. Whenever there is the least doubt





Fig. 455.—A shows the incisions employed for the removal of an adherent growth of the splenic flexure. To enable mobilization to be carried out the cross cut through the rectus had to be employed. *The patient* was operated upon by Paul's method and was alive and well ten years afterwards. B shows the incision used for the removal of an adherent growth of the ascending colon with *many glands*. The bowel from the ileum to the middle of the tra
employed for an adherent growt
carried

of the integrity of the suture line a strand of rubber or softened tube to make a track for drainage should be brought from its neighbourhood to the surface. Many surgeons are opposed to this plan but the writer is convinced of its great value.

Extra-abdominal resection.—There are some special methods of resection applicable to the large intestine which are favoured by many surgeons. Of these the methods of Paul (1895) and Mickulicz (1902) are similar in principle. They both recognize the value of conducting the resection in stages and the importance of intestinal drainage. Paul's method is the more frequently employed. If the growth has not previously been located, an exploration through a median incision is the first step. Otherwise, an incision is made directly over the growth, which is mobilized under the guidance of the eye, and the vessels in the corresponding part of the mesentery are ligatured and divided ; the loop containing the growth is thus isolated and brought outside the abdomen. The two limbs are then lightly sutured together for about 4 in. above the point at which it is considered wise to make the division of the bowel, so that they look like the barrels of a gun ; the growth is then cut away, and Paul's glass tubes are tied into either end. As a last stage, the abdominal wall is drawn together around the ends of the bowel, one or two stitches being required to fix the intestine securely to the skin. In about ten days the glass tubes loosen ; during this time the upper intestine discharges more or less freely, depending on the degree of obstruction which has been present.

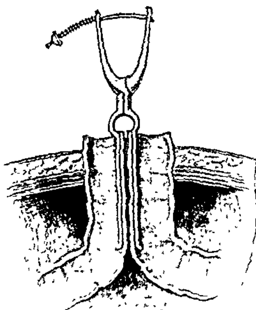


Fig. 456.—Spur between the loops of intestine clamped with an *enterotome.*

After the tubes have come away, the ends of the intestine gradually retract and the wound soon cleans up. About two weeks after the operation, if the patient is in good condition, the spur between the two loops is clamped with an enterotome before which the septum gives way, leaving a free opening between the loops. (Fig 456.) The enterotome is not intended to divide the spur but to bring about its destruction by pressure necrosis For this purpose it should be gradually tightened twice a day until it loosens. The external fistula then begins to contract and may even heal spontaneously, or it may have to be closed by a further plastic operation, making the third

stage. The whole proceeding takes two or three months. The results, both immediate and remote, are good but, to enable the bowel to be brought outside, the resection has often to be more limited than is desirable. It is perhaps in consequence of this limitation that recurrence in the scar of the abdominal wall is not uncommon.

When there has been a delay of a fortnight or more in applying the enterotome, the septum may be hard and rigid. In these circumstances it may be difficult to get the instrument to grasp the septum and stay in position, and some other method will be required. That part of the septum nearest the open end of the bowel may be destroyed with the cautery, or the bowel may be loosened from the parietes to assist its retraction. By either of these means the channel may be gradually restored, leaving the external fistula to be closed by a plastic intervention.

There are many modifications of this plan, such as making a lateral anastomosis at the first operation, the ends of the bowel being clamped and divided flush with the surface of the abdominal wall. When the anastomosis begins to function, the bowel retracts into the abdomen and the external fistula contracts and may even close spontaneously, though it usually requires some local intervention to complete the process. It may be that it is the retraction of the bowel which encourages the anastomosis to function, and this can be aided by the regular use of small enemata to secure emptying of the rectum. Yet another plan is to remove the growth, make a lateral anastomosis, and then close the bowel ends, leaving them anchored to the parietes just beneath the skin, so that if anything goes wrong a fæcal fistula can readily form. This often closes spontaneously.

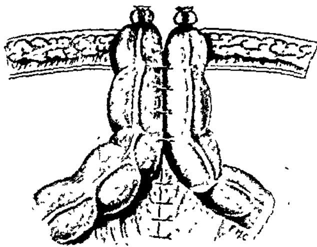


Fig. 457.—Obstructive resection. The limbs of the colon are sutured together and the ends are in the grasp of crushing clamps flush with the abdominal skin surface.

In **obstructive resection** (Fig. 457) the limbs of the loop are sutured together and are clamped at the skin level. The clamps are kept in position for three or four days, until the parts are safely sealed off and are then removed when there is no risk of a spreading infection. After about a week, the enterotome can be applied as in the original method.

Any of these methods may be employed after preliminary bowel drainage by cæcostomy or colostomy.

Even in cases where the growth can be easily mobilized, many

surgeons are in favour of the Paul operation. This is especially indicated in growths of the colon between the hepatic flexure and terminal sigmoid, a region in which about 70 per cent. of cases of cancer of the large intestine are situated.

The advocates of the many-stage operation point to the fact that immediate restoration of continuity in this region is made dangerous by the solid nature and high infectivity of the intestinal contents, by defective peritoneal covering, and by the difficulty of serous approximation owing to fat-deposit. Many patients are debilitated, and leakage and septic complications are not infrequent.

Defunctioning colostomy.—It was in an endeavour to diminish these risks that Sir Hugh Devine introduced the method known as the defunctioning or disconnecting colostomy.* In cæcostomy, and to a lesser extent in ordinary colostomy, some of the fæcal contents find their way into the distal portion of the bowel which, in consequence, remains contaminated and does not enjoy complete physiological rest. To overcome these defects Devine devised a type of colostomy in which the two openings were so far separated from each other and were so small that the risk of contamination from one to the other was practically eliminated Further, by treatment of the isolated distal loop he attempted to bring about "debacterialization" of the involved segment.

The much greater safety with which the intra-abdominal methods may now be used is tending to favour their general adoption.

Patients who have been properly prepared usually have very little trouble. A mild degree of shock may require some restorative measures. Vomiting has been much less often seen since the regular use of the Ryle's tube. The immediate pain will be relieved by morphia but this should only be given in small doses and as required, never just as a routine. Aspirin in some patients acts like a charm. During the first 48 hours a certain degree of ileus is physiological. Intravenous fluid should be given as required and most patients will be helped by glucose-saline solution Anæmic patients or those who respond badly may be improved by blood transfusion.

Small quantities of fluid by the mouth or even mouth washings have a good psychological effect. Dilute fruit juice with glucose in small amounts but given frequently may be permitted during the first 48 hours. When flatus begins to move, the rectal tube may be a comfort and if very troublesome a glycerine enema or suppository may assist passage. There is no need to fuss about the bowels and no unassisted action is to be expected sooner than about the fifth day. Liquid paraffin by mouth may be given from the first unless resented by the patient Venous circulation should be promoted by movement in bed and deliberate breathing exercise and the patient should be encouraged to help in turning and moving. The systematic use of

* *Brit. Med. Journ.*, Dec. 28, 1935, ii, 1245.

heparin for the prevention of thrombosis and embolism is still on trial and some very competent surgeons are impressed by its value.

Patients may be allowed out of bed after about four days but if they are reluctant or frightened they need not be urged until after the tenth day. Those who have submitted to such an operation deserve an adequate rest if they enjoy it. A stay in hospital for as long as 15–21 days is perfectly reasonable.

General after-treatment.—If there has been preliminary drainage of the colon the subsequent progress is much simplified. At the end of three or four days any tube is removed from the rectum, and, if there has been no evacuation by the end of a week, a glycerine enema may be given. This may bring away a small stool which has accumulated in the bowel. After that, flatus may be passed occasionally or the patient may even have the bowel moved naturally. It is well to remember that impaction of fæces may occur, this occurrence being suggested by the symptoms and confirmed by digital examination. In any event it is not wise to close the cæcostomy until at least three weeks after the resection, and if the latter has been difficult or there has been some subsequent trouble, say from infection, it is better to wait a week or two longer. To close the cæcostomy too early is to risk a fistula developing through the wound used for the resection.

NON-OBSTRUCTED CASES

These can be subdivided into two groups—(1) those in which a radical operation can be attempted, and (2) those in which, because of visceral or peritoneal metastases, such an operation is inadvisable or impossible

(1) **When a radical operation is possible.**—The radical operation consists in adequate removal of the diseased segment together with its corresponding lymphatic area, preservation of the blood supply of the parts left behind, and restoration of the continuity of the intestinal canal The type of operation depends on the arterial supply and the extent of the serous covering. The distribution of the arterial supply and its relation with the lymphatics varies so much in different parts of the colon that the extent of the resection required differs considerably. Thus, in cancer of the *cæcum, ascending colon, or hepatic flexure,* it is necessary, in order to make a safe lymphatic clearance, to remove all that part of the intestine which is supplied by the ileo-colic branch of the superior mesenteric artery. As the right colic is often given off from the ileo-colic artery, the part resected must be that contained between the lowest part supplied by the last ileal branches of the superior mesenteric and the highest part supplied by the middle colic, amounting to the last 6 in. of the ileum, the cæcum, ascending colon, hepatic flexure and a portion of the right half of the transverse colon. (Figs 458 to 463.) Restoration of continuity by means of an end-to-end ileo-transverse anastomosis is comparatively safe and easy.

The ileum can usually be readily united to the divided colon end-to-end, but if there is great disparity the ileum may be cut across obliquely or the end of the colon may be diminished by suture. (Fig. 450.)

In cancer of the *transverse colon*, resection, with removal of the paracolic glands and end-to-end anastomosis, is recommended, and generally speaking the same course is to be followed in cancer of the *iliac colon*, where there is a complete serous covering (Fig. 460).

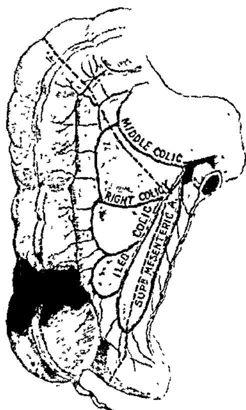


Fig. 458 a.—Diagram showing parts resected in growths of ileo-cæcal valve, cæcum, and ascending colon.

The division of the large bowel is usually made in the transverse colon beyond the hepatic flexure

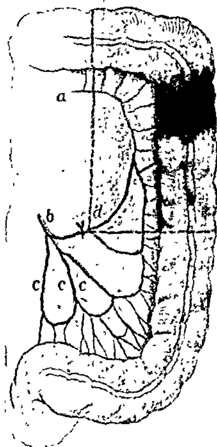


Fig. 458 b.—Diagram of splenic flexure resection.

a, Middle colic artery; *b*, inferior mesenteric artery, *c*, sigmoid branches, *d*, left colic artery

In cancer of the *splenic flexure and descending colon* a wide resection is necessary to ensure a good blood supply to the anastomotic ends (Figs. 458b and 459), and, owing to the absence of a complete serous coat in the descending colon, the aim, if direct union is to be attempted, must be an anastomosis between the iliac and transverse colon after complete mobilization. The restoration of continuity in these cases can usually be done by the end-to-end method, but it may be difficult. If it is impossible, it will be necessary, after resection of the growth and closure of both ends, to anastomose either the cæcum or the ileum to the sigmoid by the lateral method.

Generally speaking, the arterial branches supplying the colon are of

considerable size and capable of carrying on the nutrition of the bowel for quite a distance from their source. But this can only be determined by actually seeing or feeling the vessels pulsating, or inspecting the bleeding ends of the bowel after temporary removal of the clamps. In these circumstances it is safe to make a direct anastomosis, though it is always wise to provide a track by a rubber strand or small softened tube from the region of the union to the surface.

A more limited resection of the descending colon than that shown in Fig. 459 may be adequate so far as removal of the growth is concerned, but the restoration of the bowel depends first on the blood supply and second on approximation without tension, and these conditions can usually be best subserved by the wide removal of bowel.

In cancer of the *pelvic colon* (Fig. 461), there are three alternatives—(1) excision of the diseased area with end-to-end anastomosis direct or by invagination or anastomosis to the anus by one of the pull-through methods, (2) excision of the diseased area with permanent colostomy and closure of the lower end, and (3) permanent colostomy with removal of the pelvic colon and rectum (abdomino-perineal excision).

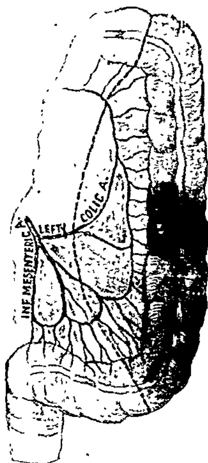


Fig. 459.—Diagram showing parts resected in growths of descending colon.

(2) **When a radical operation is impossible.**—In this group, where for one reason or another the growth cannot be removed, the object is limited to the prevention of obstruction. This may be attained by a short circuit, which is the ideal plan, or by permanent external drainage by colostomy according to the situation of the growth.

Cases where Obstruction is Present

Operations in the presence of obstruction are always difficult, and attended with a high mortality-rate. It may be taken as a general rule that a great deal will be gained if it is possible to relieve the obstruction before operation. It is well known that obstruction of the large gut, especially of the left colon and rectum, may exist for long periods without causing acute symptoms. It is also recognized that in some cases the exciting cause of the stoppage is the impaction of hardened fæcal masses, food particles or foreign bodies in the constricted portion of the intestine In obstruction due to stricture

at the lower end of the left colon, an attempt may be made, by limiting food by the mouth, by the administration of suitable laxatives with salines, and by repeated enemata, to overcome the obstruction before operating (*see* p. 1088). This treatment cannot be continued for more than a short period, even in definitely chronic cases, as the patient, who is probably debilitated, cannot maintain strength without nourishment, and because—and this is very important—in these long-standing cases there is a tendency to perforation of stercoral

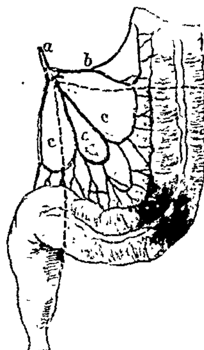


Fig. 460.—Diagram showing parts resected in growths of iliac colon.

a, Inferior mesenteric artery, *b*, left colic artery, *c*, sigmoid branches.

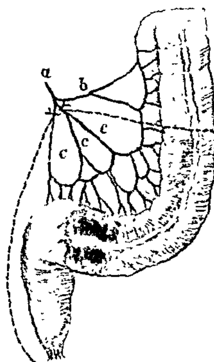


Fig. 461.—Diagram showing parts resected in growths of pelvic colon. The shaded parts are those removed in abdomino-perineal resection of the rectum.

(For references, *see* previous figure)

ulcers, either immediately above the stricture *or in the cæcum*. When signs of acute obstruction have been superadded to the chronic, the time for palliative treatment has passed. When in doubt, a preliminary cæcostomy is the safest rule.

It is a cardinal rule that *in cases of obstruction it is unjustifiable to attempt a radical cure in one stage*, i.e. resection of the affected area and restoration of continuity. All the evidence goes to prove that this procedure is attended by an unjustifiable mortality, and the practice is now universally abandoned. The first step is to relieve the obstruction, and no more should be done at this stage.

The method adopted must vary with the position of the growth and the possibility of eventually doing a radical cure, so that here also there will be two groups—(1) where obstruction is present with

an operable growth, (2) where obstruction is present with an inoperable growth.

(1) **Obstruction with operable growth.**—The object in view is to relieve the obstruction, and on a subsequent occasion to perform a radical operation, i.e removal of the growth with the affected lymphatics, and restoration of the continuity of the intestinal canal. In this group the many-stage operation is particularly indicated.

When the obstructive symptoms are marked and the abdomen is distended, blind cæcostomy, or when the growth is known to be in a suitable situation, a transverse colostomy is the method of choice and presents most advantages to the patient.

When the symptoms are milder and the abdomen is not distended, the procedure recommended is a midline subumbilical incision long enough to admit the hand, exploration to determine the site of the growth and the prospects of a radical cure, and, if this is favourable, closure of the wound and the formation of a cæcostomy through a separate opening. This applies to colonic obstruction at or beyond the hepatic flexure. In cases of obstruction at or near the ileo-cæcal valve, and in the rare cases of obstruction due to a growth of the ascending colon, a short-circuit (ileo-transverse colostomy) is the preliminary operation of choice, and is preferable to an enterostomy in the small intestine

(2) **Obstruction with inoperable growth.**—The ideal in these cases is to relieve the obstruction, and by such means as shall prevent its recurrence. This may be achieved by palliative resection, short-circuit or an artificial anus, and though the surgeon may aim at the former, circumstances may force him to adopt the latter. The deciding factor is usually the site of the growth. In the majority of cases (75 per cent.) the growth is either in the rectum or the pelvic colon, and in that situation a short-circuit is usually impossible, and an artificial anus has to be chosen.

If the growth is in the cæcum or at the ileo-cæcal valve, the operation of choice is an ileo-colostomy either to the ascending colon or to the first part of the transverse colon. When the obstructing growth is at or near the hepatic flexure, the cæcum can sometimes be united to the transverse colon or sigmoid. This must never be attempted unless the parts can be approximated without tension.

The attempt to short-circuit an obstructive growth in the transverse colon or splenic flexure introduces the objectionable feature of the cul-de-sac, and for this reason an ileo-[illegible] whenever possible. A colo-colostomy [illegible] not be made too near to the growth, as there is a tendency for the anastomotic opening to be invaded. If this anastomosis cannot be made, the surgeon must decide between (1) a permanent artificial anus proximal to [illegible] by division of th[illegible] ostomy (side-to-side or end-to-side), with drainage of the excluded

segment proximal to the obstruction (*see* p. 1071). For permanent purposes colostomy in the transverse is not quite such a satisfactory operation as in the iliac colon, but the opening can be well protected by a belt.

Technique of radical operations in the different parts of the colon. Ileo-cæcal valve, cæcum, and ascending colon, including the hepatic flexure. —Even when the question of obstruction does not arise, many of these cases are best dealt with by a two-stage method and this especially applies to those with very fixed growths, those of large size, or where other organs are also invaded or when the patient is in poor condition. The first stage comprises exploration and short-circuiting, usually ileo-colostomy by the end-to-side or side-to-side method and the second removal of the growth and right half of the colon. For the removal a vertical incision is usually employed, either in the middle line below the umbilicus or through the right rectus. An oblique or directly transverse approach (Fig. 455, B) is very satisfactory and often essential with large fixed growths. If the surgeon starts off with a vertical incision and finds himself embarrassed for want of access he should never hesitate to make a cross-cut towards the loin. The cæcum and ascending colon are mobilized by freely dividing the peritoneum as it passes from the colon to the parietes, and elevated towards the middle line by blunt dissection. (Fig. 462.) During this step great care must be taken because the second part of the duodenum and the ureter are apt to be stripped up with the bowel. Unless these structures are infiltrated by growth or involved in inflammatory exudate they can be easily separated once they have been identified. In the rare cases where the duodenum is invaded by the growth a piece of the convexity may be safely cut away, the resulting defect in its wall being repaired in the transverse axis. The fact that the duodenum is uncovered by peritoneum does not interfere with healing provided two layers of sutures are carefully employed. If the ureter is involved it may be possible to cut away a section and to restore continuity, or to implant the proximal end into the large bowel, or the corresponding kidney may be excised, or the ends simply ligatured and allowed to retract into the cellular tissue. Not infrequently the fascia covering the iliacus, or even the muscle itself, is invaded. In these circumstances part of the muscle must be removed. The surgeon must take care not to injure the anterior crural (femoral) nerve at the outer border of the psoas or the iliac vessels at the inner border. The process of mobilization is continued until the ileo-colic artery is exposed at its origin from the superior mesenteric. The cæcum and ascending colon, with the last part of the ileum, can now be withdrawn from the abdomen and, if the mesentery is not too much loaded with fat, the ileo-colic and middle colic artery with its branches can be clearly seen or their situation demonstrated by trans-illumination. The ileo-colic artery and vein are tied as near their origin as possible and divided between

ligatures. A point on the ileum about 6 in. from the ileo-cæcal valve is chosen, and an opening is made through the mesentery as near the intestine as possible. The vessels are controlled by pressure forceps, and the mesentery incised towards its attachment, the anastomotic branches between the ileo-colic artery and the terminal intestinal artery being secured. The ileum is then held in two pairs of clamps and divided between them. If it is intended to restore continuity by

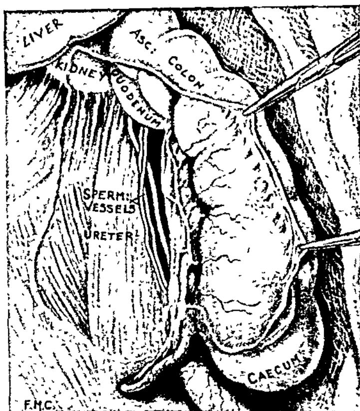


Fig. 462.—Resecting ascending colon : first stage.

The parietal peritoneal reflexion has been incised, and the colon lifted from its bed by blunt dissection. Note duodenum and kidney exposed

implanting the proximal end of the ileum into the transverse colon (end-to-side) or by end-to-end anastomosis, this end is left in the grasp of a clamp, for the time wrapped up in a moistened gauze pad. If it is intended to do a side-to-end (side of ileum to cut end of transverse colon) or a lateral anastomosis with the transverse colon, the cut end of the ileum is closed by ligation or a running suture through all coats, and is inverted and covered in by a purse-string suture the end of which is left long as a convenient handle.

A point is now chosen on the transverse colon, preferably just beyond the hepatic flexure, and in any case at least 3 in. beyond the growth. If this is within the attachment of the great omentum, it should be cleared by stripping the omentum off the bowel by a scalpel close to its attachment. An incision is made through the mesentery and extended

segment proximal to the obstruction (see p. 1071). For permanent purposes colostomy in the transverse is not quite such a satisfactory operation as in the iliac colon, but the opening can be well protected by a belt.

Technique of radical operations in the different parts of the colon. Ileo-cæcal valve, cæcum, and ascending colon, including the hepatic flexure. —Even when the question of obstruction does not arise, many of these cases are best dealt with by a two-stage method and this especially applies to those with very fixed growths, those of large size, or where other organs are also invaded or when the patient is in poor condition. The first stage comprises exploration and short-circuiting, usually ileo-colostomy by the end-to-side or side-to-side method and the second removal of the growth and right half of the colon. For the removal a vertical incision is usually employed, either in the middle line below the umbilicus or through the right rectus. An oblique or directly transverse approach (Fig. 455, B) is very satisfactory and often essential with large fixed growths. If the surgeon starts off with a vertical incision and finds himself embarrassed for want of access he should never hesitate to make a cross-cut towards the loin. The cæcum and ascending colon are mobilized by freely dividing the peritoneum as it passes from the colon to the parietes, and elevated towards the middle line by blunt dissection. (Fig. 462.) During this step great care must be taken because the second part of the duodenum and the ureter are apt to be stripped up with the bowel. Unless these structures are infiltrated by growth or involved in inflammatory exudate they can be easily separated once they have been identified. In the rare cases where the duodenum is invaded by the growth a piece of the convexity may be safely cut away, the resulting defect in its wall being repaired in the transverse axis The fact that the duodenum is uncovered by peritoneum does not interfere with healing provided two layers of sutures are carefully employed. If the ureter is involved it may be possible to cut away a section and to restore continuity, or to implant the proximal end into the large bowel, or the corresponding kidney may be excised, or the ends simply ligatured and allowed to retract into the cellular tissue. Not infrequently the fascia covering the iliacus, or even the muscle itself, is invaded. In these circumstances part of the muscle must be removed. The surgeon must take care not to injure the anterior crural (femoral) nerve at the outer border of the psoas or the iliac vessels at the inner border. The process of mobilization is continued until the ileo-colic artery is exposed at its origin from the superior mesenteric. The cæcum and ascending colon, with the last part of the ileum, can now be withdrawn from the abdomen and, if the mesentery is not too much loaded with fat, the ileo-colic and middle colic artery with its branches can be clearly seen or their situation demonstrated by trans-illumination The ileo-colic artery and vein are tied as near their origin as possible and divided between

ligatures. A point on the ileum about 6 in. from the ileo-cæcal valve is chosen, and an opening is made through the mesentery as near the intestine as possible. The vessels are controlled by pressure forceps, and the mesentery incised towards its attachment, the anastomotic branches between the ileo-colic artery and the terminal intestinal artery being secured. The ileum is then held in two pairs of clamps and divided between them. If it is intended to restore continuity by

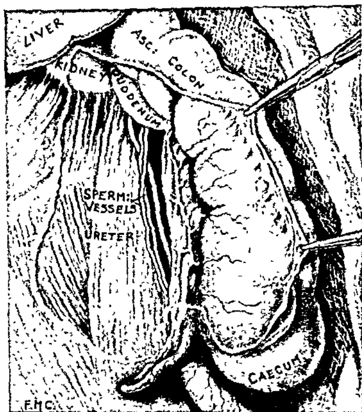


Fig. 462.—Resecting ascending colon: first stage.

The parietal peritoneal reflexion has been incised, and the colon lifted from its bed by blunt dissection. Note duodenum and kidney exposed.

implanting the proximal end of the ileum into the transverse colon (end-to-side) or by end-to-end anastomosis, this end is left in the grasp of a clamp, for the time wrapped up in a moistened gauze pad. If it is intended to do a side-to-end (side of ileum to cut end of transverse colon) or a lateral anastomosis with the transverse colon, the cut end of the ileum is closed by ligation or a running suture through all coats, and is inverted and covered in by a purse-string suture the end of which is left long as a convenient handle.

A point is now chosen on the transverse colon, preferably just beyond the hepatic flexure, and in any case at least 3 in. beyond the growth. If this is within the attachment of the great omentum, it should be cleared by stripping the omentum off the bowel by a scalpel close to its attachment. An incision is made through the mesentery and extended

towards its attachment, the anastomotic branches between the middle colic and the ileo-colic and right colic arteries being secured before they are cut. The colon is then clamped by two pairs of forceps at the point selected, and is divided between them. (Fig. 463.) If it is decided to restore continuity by implanting the ileum into the colon (end-to-side) or by lateral anastomosis, the distal end of the divided

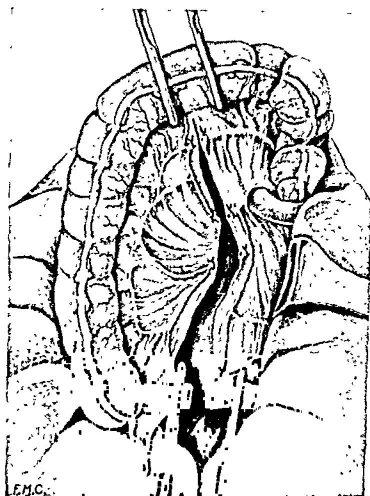


Fig. 463.—Resecting ascending colon : second stage.

colon is closed in the same manner as the ileum, a step which is made much easier if the great omentum has l
advised. *It is tempting to occlude the*
and to tuck in the end after applying a
may be easily accomplished in a thin, attenuated bowel but otherwise may be difficult and unsatisfactory The portion of intestine to be removed is now isolated, and is attached *only by the remains of its mesentery.* This mesenteric attachment is very methodically mobilized, the section of intestine being separated still farther towards the middle line by wiping the mesentery upwards and inwards from the posterior wall. Great care must be taken not to injure the duodenum By this means a very complete block-removal of the lymphatic area can be

achieved. The base of the mesentery is caught in sections by artery forceps and is divided between them, and the intestine with its mesentery removed. Continuity may also be restored by end-to-end anastomosis, which is strongly recommended. This method is often easy and satisfactory, the ileum being dilated enough to make it fit the end of the colon, but if there is marked disproportion, it can be cut obliquely, or the side of the cut end of the colon may be diminished by suture (Fig. 450). The union is made by direct suture with two layers of chromic catgut.

The final stage consists in an endeavour to repair the peritoneal gap which has resulted from the separation of the resected segment from the posterior abdominal wall. The free edge of the mesentery of the ileum may be united to the free edge of the transverse mesocolon, thus reducing the gap considerably, and it may even be found possible by careful suturing to cover in the remaining area. If it is not feasible to cover the bare area completely, it should be reduced as much as practicable by drawing the peritoneum over the denuded structures as far as that can be accomplished without tension. It is then fixed to the underlying parts by a stitch here and there to prevent its retraction. In this region no harm will follow even if a considerable area has to be left uncovered. When a portion of the iliacus muscle has been taken away the area must be packed with gauze. There is often a good deal of oozing which cannot be easily arrested, and it is wise to leave in a softened drainage-tube or a tissue drain with the gauze.

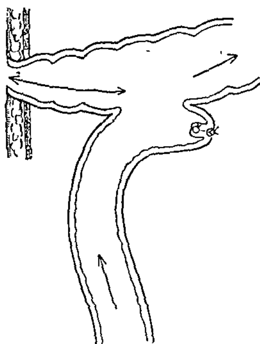


Fig. 464.—Method of temporary bowel drainage after excision of the cæcum or right colon.

Temporary enterostomy in removal of cæcal growths.—This may be a wise precaution where the operation has been carried out in one stage in the presence of some degree of obstruction, as shown by distension of the ileum with fluid contents, or when the surgeon for any reason is not very confident about the suturing. A catheter may be placed in the ileum about a foot above the anastomosis, using the same technique as in jejunostomy. Or the plan indicated in Fig. 464 may be adopted. If the first method is employed, the catheter may be removed at the end of a week or ten days, when this type of enterostomy usually closes spontaneously. In the other plan the colonic fistula may heal naturally or it may have to be deliberately

closed at the end of two or three weeks, or sooner, if the discharge is very liquid and troublesome.

Transverse colon.—This part of the bowel has a simple blood supply, a lymphatic area which is but little invaded except in the vicinity of the growth, and usually a long mesentery which allows free movement and easy approximation. The only difficulty lies in the presence of the great omentum, but the part corresponding to the bowel to be excised should be taken away with the growth. The omentum by the side of the divided bowel should be separated from the colon for a short distance, as this facilitates the anastomosis. *At least 3 in. of bowel on either side of the edge of the growth should be removed.*

An incision is made through the mesentery, as near to the gut as possible at the point of proposed section of the bowel, and extended towards the root of the mesocolon to include a V-shaped area. The mesentery is doubly caught in large artery forceps and is divided between them All bleeding-points being secured, the colon is doubly clamped at the agreed line of section and divided. The same course is followed on the other side of the growth.

The two clamps, controlling the ends to be sutured, are wrapped in moist gauze swabs and put aside for the moment.

The segment to be resected is now held only by the gastro-colic omentum. The great omentum is divided by vertical incisions extending from the point of section to its free edge on both sides, and all bleeding controlled For this purpose strong artery forceps with good holding surfaces should be employed and ligatures should be tied firmly and slowly to diminish the risk of retraction of the blood-vessels. The gastro-colic omentum is then tied off by transfixion close to the greater curvature of the stomach, but preserving the gastro-epiploic vessels. The clamps holding the distal and proximal cut ends of the bowel are approximated, and an end-to-end axial *anastomosis made. The gap in the mesentery is closed, and the operation completed by suturing or ligaturing together the two portions* of what is left of the great omentum and gastro-colic omentum.

Splenic flexure and descending colon.—The resection of this portion of the colon is the most difficult of all. Partial or complete intestinal obstruction is often present (in 60 per cent. of cases), and resection can be undertaken only after the obstruction has been relieved by a preliminary operation The flexure is situated high up under the ribs *in the left hypochondrium, it rarely has a complete serous investment,* it is in close relation with the spleen and left kidney, and is retained in position by a strong costo-colic ligament In addition, it is often fixed by adhesions associated with the growth The latter is generally of the scirrhous constricting type, and lymphatic metastasis is limited. It is in these cases that a parietal incision directly over the growth is invaluable. When, as the result of previous exploration, the surgeon knows exactly with what he has to deal, an oblique incision about an inch below the costal margin and not less than six inches

long, will give an admirable exposure. Otherwise a cross cut may be made from a vertical incision. (Fig. 455, A, p. 1085.)

Owing to the absence of a complete peritoneal coat, the difficulty of getting the ends together without tension, and sometimes doubt about the adequacy of the blood supply, these cases are not so suitable for local resection and end-to-end anastomosis, and it is unlikely that there will be room enough for lateral anastomosis, which requires a considerable overlap. The secret of success is adequate mobilization and the removal of much more bowel than the pathological state appears to indicate. The ideal operation is to resect all that part of the colon supplied by the left colic artery, with its mesentery and lymphatic drainage system, up to the origin of the artery, and to restore continuity by anastomosing the left end of the transverse colon to the upper end of the iliac colon, either by the axial end-to-end or the lateral method. This may be greatly facilitated by freely mobilizing the iliac colon, especially at its upper end where it is often bound down, by dividing the peritoneal reflection between it and the postero-lateral wall of the abdomen. It is in these cases that a preliminary cæcostomy is so great a safeguard, and, if it has not been done before, it is wise to make a valvular opening into the cæcum at the conclusion of the operation. A rubber tissue or softened tube to the surface from the site of the anastomosis often saves a disaster. These cases may be complicated by direct involvement of the surrounding viscera, but this is not necessarily an obstacle to successful removal. This aspect of the matter is shown in Figs. 453 and 466, pp. 1077, 1107.

Sigmoid flexure or iliac colon.—Resection of a growth in this region is comparatively easy. The flexure has a long mesentery, it is easily mobilized, it has a complete peritoneal investiture, and the growths tend to be of the constricting type without adhesions or extensive lymphatic involvement. The only difficulty arises from the appendices epiploicæ, which may interfere with the accurate coaptation of the serous coat. After preliminary mobilization, if this is necessary, allowing the flexure to be freely withdrawn from the abdomen, the procedure followed is simple excision with end-to-end axial anastomosis.

There are those who recommend lateral anastomosis here, on the ground that leakage is less likely. La[illegible] two disadvantages: (1) it needs a grea[illegible] reduces the amount that can be removed, and (2) the proximal blind end may become distended and may ulcerate and even perforate. Lockhart Mummery, who is a firm advocate of end-to-end union in the colon, considers that leakage is due to necrosis of the edges of the bowel where they are stitched together, and that this results from the circular type of arterial distribution to the wall, and can be obviated by cutting the bowel at an angle of 45° to its transverse diameter. Great care should also be taken not to occlude obvious vessels with the sutures, and the whole anastomosis should be protected by neighbouring appendices epiploicæ which should be fixed here and

closed at the end of two or three weeks, or sooner, if the discharge is very liquid and troublesome.

Transverse colon.—This part of the bowel has a simple blood supply, a lymphatic area which is but little invaded except in the vicinity of the growth, and usually a long mesentery which allows free movement and easy approximation. The only difficulty lies in the presence of the great omentum, but the part corresponding to the bowel to be excised should be taken away with the growth. The omentum by the side of the divided bowel should be separated from the colon for a short distance, as this facilitates the anastomosis. At least 3 in. of bowel on either side of the edge of the growth should be removed.

An incision is made through the mesentery, as near to the gut as possible at the point of proposed section of the bowel, and extended towards the root of the mesocolon to include a V-shaped area. The mesentery is doubly caught in large artery forceps and is divided between them. All bleeding-points being secured, the colon is doubly clamped at the agreed line of section and divided. The same course is followed on the other side of the growth.

The two clamps, controlling the ends to be sutured, are wrapped in moist gauze swabs and put aside for the moment.

The segment to be resected is now held only by the gastro-colic omentum. The great omentum is divided by vertical incisions extending from the point of section to its free edge on both sides, and all bleeding controlled. For this purpose strong artery forceps with good holding surfaces should be employed and ligatures should be tied firmly and slowly to diminish the risk of retraction of the blood-vessels. The gastro-colic omentum is then tied off by transfixion close to the greater curvature of the stomach, but preserving the gastro-epiploic vessels. The clamps holding the distal and proximal cut ends of the bowel are approximated, and an end-to-end axial anastomosis made. The gap in the mesentery is closed, and the operation completed by suturing or ligaturing together the two portions of what is left of the great omentum and gastro-colic omentum.

Splenic flexure and descending colon.—The resection of this portion of the colon is the most difficult of all. Partial or complete intestinal obstruction is often present (in 60 per cent of cases), and resection can be undertaken only after the obstruction has been relieved by a preliminary operation. The flexure is situated high up under the ribs in the left hypochondrium, it rarely has a complete serous investment, it is in close relation with the spleen and left kidney, and is retained in position by a strong costo-colic ligament. In addition, it is often fixed by adhesions associated with the growth. The latter is generally of the scirrhous constricting type, and lymphatic metastasis is limited. It is in these cases that a parietal incision directly over the growth is invaluable. When, as the result of previous exploration, the surgeon knows exactly with what he has to deal, an oblique incision about an inch below the costal margin and not less than six inches

long, will give an admirable exposure. Otherwise a cross cut may be made from a vertical incision. (Fig. 455, A, p. 1085.)

Owing to the absence of a complete peritoneal coat, the difficulty of getting the ends together without tension, and sometimes doubt about the adequacy of the blood supply, these cases are not so suitable for local resection and end-to-end anastomosis, and it is unlikely that there will be room enough for lateral anastomosis, which requires a considerable overlap. The secret of success is adequate mobilization and the removal of much more bowel than the pathological state appears to indicate. The ideal operation is to resect all that part of the colon supplied by the left colic artery, with its mesentery and lymphatic drainage system, up to the origin of the artery, and to restore continuity by anastomosing the left end of the transverse colon to the upper end of the iliac colon, either by the axial end-to-end or the lateral method. This may be greatly facilitated by freely mobilizing the iliac colon, especially at its upper end where it is often bound down, by dividing the peritoneal reflection between it and the postero-lateral wall of the abdomen. It is in these cases that a preliminary cæcostomy is so great a safeguard, and, if it has not been done before, it is wise to make a valvular opening into the cæcum at the conclusion of the operation. A rubber tissue or softened tube to the surface from the site of the anastomosis often saves a disaster. These cases may be complicated by direct involvement of the surrounding viscera, but this is not necessarily an obstacle to successful removal. This aspect of the matter is shown in Figs. 453 and 466, pp. 1077, 1107.

Sigmoid flexure or iliac colon.—Resection of a growth in this region is comparatively easy. The flexure has a long mesentery, it is easily mobilized, it has a complete peritoneal investiture, and the growths tend to be of the constricting type without adhesions or extensive lymphatic involvement. The only difficulty arises from the appendices epiploicæ, which may interfere with the accurate coaptation of the serous coat. After preliminary mobilization, if this is necessary, allowing the flexure to be freely withdrawn from the abdomen, the procedure followed is simple excision with end-to-end axial anastomosis.

There are those who recommend lateral anastomosis here, on the ground that leakage is less likely. Lateral anastomosis has, however, two disadvantages: (1) it needs a greater length of gut and therefore reduces the amount that can be removed, and (2) the proximal blind end may become distended and may ulcerate and even perforate. Lockhart Mummery, who is a firm advocate of end-to-end union in the colon, considers that leakage is due to necrosis of the edges of the bowel where they are stitched together, and that this results from the circular type of arterial distribution to the wall, and can be obviated by cutting the bowel at an angle of 45° to its transverse diameter. Great care should also be taken not to occlude obvious vessels with the sutures, and the whole anastomosis should be protected by neighbouring appendices epiploicæ which should be fixed here and

ed at the end of two or three weeks, or sooner, if the discharge is liquid and troublesome.

ransverse colon.—This part of the bowel has a simple blood supply, mphatic area which is but little invaded except in the vicinity of growth, and usually a long mesentery which allows free movement easy approximation. The only difficulty lies in the presence of the t omentum, but the part corresponding to the bowel to be excised ıld be taken away with the growth. The omentum by the side ıe divided bowel should be separated from the colon for a short ınce, as this facilitates the anastomosis. At least 3 in. of bowel ither side of the edge of the growth should be removed.

ı incision is made through the mesentery, as near to the gut as ible at the point of proposed section of the bowel, and extended ırds the root of the mesocolon to include a V-shaped area. The entery is doubly caught in large artery forceps and is divided veen them. All bleeding-points being secured, the colon is doubly ıped at the agreed line of section and divided. The same course llowed on the other side of the growth.

ıe two clamps, controlling the ends to be sutured, are wrapped ıoist gauze swabs and put aside for the moment.

ıe segment to be resected is now held only by the gastro-colic ntum. The great omentum is divided by vertical incisions nding from the point of section to its free edge on both sides, all bleeding controlled For this purpose strong artery forceps good holding surfaces should be employed and ligatures should ied firmly and slowly to diminish the risk of retraction of the d-vessels. The gastro-colic omentum is then tied off by trans- n close to the greater curvature of the stomach, but preserving gastro-epiploic vessels. The clamps holding the distal and proximal ends of the bowel are approximated, and an end-to-end axial tomosis made. The gap in the mesentery is closed, and the ation completed by suturing or ligaturing together the two portions hat is left of the great omentum and gastro-colic omentum.

lenic flexure and descending colon.—The resection of this portion ıe colon is the most difficult of all. Partial or complete intestinal ruction is often present (in 60 per cent. of cases), and resection be undertaken only after the obstruction has been relieved by a iminary operation. The flexure is situated high up under the ribs ıe left hypochondrium, it rarely has a complete serous investment, in close relation with the spleen and left kidney, and is retained osition by a strong costo-colic ligament. In addition, it is often l by adhesions associated with the growth. The latter is generally ıe scirrhous constricting type, and lymphatic metastasis is limited. ; in these cases that a parietal incision directly over the growth ıvaluable. When, as the result of previous exploration, the eon knows exactly with what he has to deal, an oblique incision ıt an inch below the costal margin and not less than six inches

must be borne in mind (Fig. 465). In abdomino-perineal operations, where the whole of the intestine below the colostomy is to be removed, it is safe to tie the inferior mesenteric artery immediately below the left colic branch (Hamilton Drummond).

Resection with direct end-to-end anastomosis.—The patient is placed in the high Trendelenburg position, and the abdomen opened in the

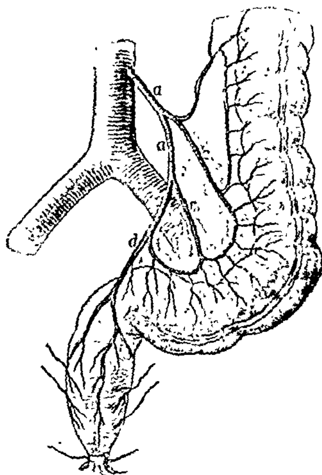


Fig. 465.—Blood supply of iliac and pelvic colon.
a, Inferior mesenteric artery; *b*, left colic artery; *c*, sigmoid branches, *d*, superior hæmorrhoidal artery.

middle line by an incision extending from the umbilicus or above it to the symphysis pubis. The middle line is chosen because it gives the best exposure of the lower end of the colon. The growth is examined, and the scope of the operation determined. The intestines having been packed upwards under swabs, the first step consists in a colo-parietal mobilization, the peritoneal reflection from the colon to the posterior pelvic wall being divided parallel with the gut for a sufficient distance to permit of the intestine being drawn up to or through the incision This may be extended so far as to free the lower part of the descending colon which is then wiped inwards until the middle line is reached In doing this the ureter may be freely exposed, and must be safeguarded ; sometimes both

there over the suture line. (Fig. 438.) *A preliminary colostomy or cæcostomy is a great safeguard.*

Pelvic colon.—Removal of growths from the pelvic colon may be very difficult. The growths, whatever the type, tend to involve the lymphatic nodes which may be invaded up to the origin of the inferior mesenteric artery. There may also be extension to the pelvic peritoneum, to the bladder or to the female pelvic organs. Sometimes fixation is merely inflammatory, but in that case separation from the bladder or vagina may demand the greatest patience. Resection should only be contemplated after preliminary colostomy, quite apart from any question of obstruction sufficient to demand that operation. When the growth is very low in the pelvis an inguinal colostomy will suffice, but for those more highly placed transverse colostomy is indicated.

Unless the degree of obstruction demands blind colostomy, a deliberate exploration should be made at the same time as the bowel is drained. For this purpose an independent mid-line incision should be employed. The oblique incision required for left inguinal colostomy can be enlarged and used for exploration, but incisional hernia invariably follows, so that finally the colostomy comes to be perched on the summit of what may be a ventral hernia of considerable size.

When the exploration discloses local extension of the growth to the peritoneum or surrounding parts, only the experience of the surgeon can enable a decision to be made concerning the prospects of further intervention. In many cases where there has been doubt of the nature of the mass it has subsequently turned out to be inflammatory. The interval between the colostomy and the further intervention will depend on the degree of improvement in the patient's condition as the result of the colostomy. During the waiting period the lower segment of the bowel must be adequately cleansed but the growth should not be irritated, or stimulated to activity, by too vigorous intervention, as physiological rest is important.

When resection can be done the distal end is always short, and tends to be difficult to handle, owing to contraction and retraction. There is a choice of several methods of dealing with the gut after resection: (1) *End-to-end anastomosis by direct suture*; (2) end-to-end anastomosis by invagination; (3) making an artificial anus by fixing the proximal end to the abdominal wall through a separate incision, combined with closure and infolding of the distal end; (4) abdomino-perineal excision; or (5) one of the abdomino-anal methods where the pelvic colon is drawn into the anal canal and sutured there or brought completely outside and anchored to the skin. The type of operation can only be decided on after opening the abdomen, and depends upon the extent of the disease, the accessibility of the lower end, and the degree of mobilization of the sigmoid and descending colon which can be secured. In all cases where end-to-end anastomosis is contemplated, the peculiarity of the circulation between the superior hæmorrhoidal artery and the inferior sigmoid artery

holder are essential. The posterior part of the union should be made with mattress sutures, the remainder of the circumference of the bowel being united by a continuous stitch. If this is too difficult to apply, or there is disproportion in the size of the ends, a few interrupted sutures may secure fair apposition. This first layer must then be buried by further sutures passed Lembert-fashion, despite the fact that the lower end is often without peritoneum. After the union is completed it may be possible to provide further protection by drawing some of the pelvic cellular tissue or the pelvic peritoneum up to the bowel and fixing it by a few points of suture about the anastomosis. It is essential that a thumb-sized rubber tube should be passed up from the anus to beyond the anastomosis and it is always wise to bring a rubber strand from the pelvis up out of the lower end of the abdominal incision. If there has been much risk of soiling from the bowel or if the suture line is obviously insecure, it is better to pack the cellular tissue of the pelvis, the suture line being protected from actual contact with the gauze by strips of rubber tissue. This pack must be left for at least four days and should only be removed piecemeal. Working at this depth, the union can seldom be accurately made and it cannot be expected to be watertight. For this reason the operation should never be attempted in one stage, and indeed, is scarcely advisable except with the protection of a preparatory colostomy and in these times the protection afforded by chemotherapy. Nevertheless, the union is often entirely satisfactory though a temporary fæcal fistula may occur. The tube should be removed from the rectum at the end of a week, but no attempt should be made to close the colostomy until the abdominal incision is soundly healed, and this will probably be from three to four weeks post-operatively. This operation is a serious procedure which has been attended by a considerable mortality but in cases that recover the after results are good and rectal function is completely restored. Unfortunately, few deep pelvic growths are sufficiently localized to lend themselves to this method of upper or anterior conservative resection

Anastomosis by invagination.—If the lower end is considered too short or too inaccessible to warrant an attempt at end-to-end suture, this second alternative may be adopted. The steps are the same as in the preceding operation up to the stage of anastomosis. At this stage a thick-walled rubber tube, $\frac{1}{2}$ to $\frac{3}{4}$ in. in diameter and 12 in. in length, is firmly sewn into the upper end by catgut sutures. The anal sphincter is stretched and a pair of ovum or similar forceps is passed up the rectum from the anus and enters the field of operation through the lower cut end. The free end of the rubber tube is seized by these forceps and guided into the open lower end, the edges of which are steadied by temporary traction sutures. By pulling on the tube in withdrawing the forceps, the upper bowel end is approximated to the lower, and when they meet they are sutured together with a few stitches of catgut. Further traction made on the rubber tube tends to invaginate the upper end into the lower. The union is further

ureters are seen. As soon as the extra-peritoneal tissue has been exposed the finger should be introduced behind the mesocolon and gently thrust backwards into the hollow of the sacrum. From that position gentle manipulation and forward pressure with the finger frees the bowel in a wonderful way and enables it to be straightened and drawn nearer the surface. The inferior mesenteric artery is then defined, a matter of no great difficulty if the gut is well mobilized and the mesentery not too loaded with fat. It is tied immediately below the first sigmoid branch. The lower ends of the colo-parietal incisions are connected by a cross-incision through the peritoneum covering the intestine below the growth. In very low growths this connecting incision may encircle the whole of the bottom of the recto-vesical or Douglas's pouch. If this has not already been done the section to be removed is now freed from its attachments in the concavity of the sacrum by fingers thrust in behind it. If there is room a clamp with a slight curve may be applied to the bowel before division but in many low growths this is not possible. If steps have been taken in preparation with chemotherapy and to cleanse the segment of bowel below the colostomy and to empty the rectum the omission of the clamp is not a serious matter. Sometimes the growth is so near the bottom of the recto-vesical pouch that the bowel cannot be divided where it is covered with peritoneum. In that case the mobilization may be carried on right down inside the levatores ani muscles until the bowel can be divided a sufficient distance below the growth, entirely extra-peritoneally. In any case the surgeon must take care to make the division strictly horizontal. When working deep in the pelvis the best plan is to open the anterior part of the bowel with a pair of scissors and then carefully cut through the wall, section by section. This provides an opportunity for removing any fluid from the lower end by the suction apparatus or by gauze swabbing. Solid contents may be pushed down into the rectum with a strand of gauze. This strand should not be withdrawn upwards but should be retrieved from the rectum at the conclusion of the operation As the upper end of the bowel is freed it may be caught in an angular holding clamp, but the edges of the rectal end must be caught with catch forceps or guide sutures here and there as the division proceeds A few spouting vessels will have to be caught and tied. The cut ends are protected, and the mass drawn out of the abdomen. The upper line of section is now decided upon, and the gut is controlled by a clamp and divided, all bleeding-points being tied. Traction sutures are placed on the lower end, the surgeon waiting for a time to see if the cut edge bleeds in order to satisfy himself of the adequacy of the blood supply. If the lower end is sufficiently accessible, a direct *end-to-end anastomosis* by double-suture line may be carried out, the method being in no way different in plan from the ordinary end-to-end anastomosis although accurate suturing may be very difficult.

When the lower end is below the level of the peritoneum, access is exceedingly difficult. Small, round, full-curved needles used with a

holder are essential. The posterior part of the union should be made with mattress sutures, the remainder of the circumference of the bowel being united by a continuous stitch. If this is too difficult to apply, or there is disproportion in the size of the ends, a few interrupted sutures may secure fair apposition. This first layer must then be buried by further sutures passed Lembert-fashion, despite the fact that the lower end is often without peritoneum. After the union is completed it may be possible to provide further protection by drawing some of the pelvic cellular tissue or the pelvic peritoneum up to the bowel and fixing it by a few points of suture about the anastomosis. It is essential that a thumb-sized rubber tube should be passed up from the anus to beyond the anastomosis and it is always wise to bring a rubber strand from the pelvis up out of the lower end of the abdominal incision. If there has been much risk of soiling from the bowel or if the suture line is obviously insecure, it is better to pack the cellular tissue of the pelvis, the suture line being protected from actual contact with the gauze by strips of rubber tissue. This pack must be left for at least four days and should only be removed piecemeal. Working at this depth, the union can seldom be accurately made and it cannot be expected to be watertight. For this reason the operation should never be attempted in one stage, and indeed, is scarcely advisable except with the protection of a preparatory colostomy and in these times the protection afforded by chemotherapy. Nevertheless, the union is often entirely satisfactory though a temporary fæcal fistula may occur. The tube should be removed from the rectum at the end of a week, but no attempt should be made to close the colostomy until the abdominal incision is soundly healed, and this will probably be from three to four weeks post-operatively. This operation is a serious procedure which has been attended by a considerable mortality but in cases that recover the after results are good and rectal function is completely restored. Unfortunately, few deep pelvic growths are sufficiently localized to lend themselves to this method of upper or anterior conservative resection.

Anastomosis by invagination.—If the lower end is considered too short or too inaccessible to warrant an attempt at end-to-end suture, this second alternative may be adopted. The steps are the same as in the preceding operation up to the stage of anastomosis. At this stage a thick-walled rubber tube, ½ to ¾ in. in diameter and 12 in. in length, is firmly sewn into the upper end by catgut sutures. The anal sphincter is stretched and a pair of ovum or similar forceps is passed up the rectum from the anus and enters the field of operation through the lower cut end. The free end of the rubber tube is seized by these forceps and guided into the open lower end, the edges of which are steadied by temporary traction sutures. By pulling on the tube in withdrawing the forceps, the upper bowel end is approximated to the lower, and when they meet they are sutured together with a few stitches of catgut. Further traction made on the rubber tube tends to invaginate the upper end into the lower. The union is further

ureters are seen. As soon as the extra-peritoneal tissue has been exposed the finger should be introduced behind the mesocolon and gently thrust backwards into the hollow of the sacrum. From that position gentle manipulation and forward pressure with the finger frees the bowel in a wonderful way and enables it to be straightened and drawn nearer the surface. The inferior mesenteric artery is then defined, a matter of no great difficulty if the gut is well mobilized and the mesentery not too loaded with fat. *It is tied* immediately below the first sigmoid branch. The lower ends of the colo-parietal incisions are connected by a cross-incision through the peritoneum covering the intestine below the growth In very low growths this connecting incision may encircle the whole of the bottom of the recto-vesical or Douglas's pouch. If this has not already been done the section to be removed is now freed from its attachments in the concavity of the sacrum by fingers thrust in behind it. If there is room a clamp with a slight curve may be applied to the bowel before division but in many low growths this is not possible. If steps have been taken in preparation with chemotherapy and to cleanse the segment of bowel below the colostomy and to empty the rectum the omission of the clamp is not a serious matter. Sometimes the growth is so near the bottom of the recto-vesical pouch that the bowel cannot be divided where it is covered with peritoneum. In that case the mobilization may be carried on right down inside the levatores ani muscles until the bowel can be divided a sufficient distance below the growth, entirely extra-peritoneally. In any case the surgeon must take care to make the division strictly horizontal. *When working deep in the pelvis the best plan is to open the anterior* part of the bowel with a pair of scissors and then carefully cut through the wall, section by section. This provides an opportunity for removing any fluid from the lower end by the suction apparatus or by gauze swabbing. Solid contents may be pushed down into the rectum with a strand of gauze. This strand should not be withdrawn upwards but should be retrieved from the rectum at the conclusion of the operation As the upper end of the bowel is freed it may be caught in an angular holding clamp, but the edges of the rectal end must be caught with catch forceps or guide sutures here and there as the division proceeds A few spouting vessels will have to be caught and tied. The cut ends are protected, and the mass drawn out of the abdomen. The upper line of section is now decided upon, and the gut is controlled by a clamp and divided, *all bleeding-points being tied. Traction sutures* are placed on the lower end, the surgeon waiting for a time to see if the cut edge bleeds in order to satisfy himself of the adequacy of the blood supply. If the lower end is sufficiently accessible, a direct *end-to-end anastomosis* by double-suture line may be carried out, the method being in no way different in plan from the ordinary end-to-end anastomosis although accurate suturing may be very difficult

When the lower end is below the level of the peritoneum, access is exceedingly difficult. Small, round, full-curved needles used with a

commencing about the fourth day and ending by the seventh day. This method has frequently been employed and is quite reliable.

GROWTHS INVOLVING OTHER VISCERA OR THE PARIETES

In all such cases the final decision whether a radical removal can be undertaken will depend upon a preliminary abdominal exploration. If evidence of distant dissemination is absent, then no degree of local extension should deter the surgeon from at least considering the possibilities of removal. This type of case often demands multiple-stage intervention, but whether that must take the form of a preliminary colostomy or a short-circuit will be decided by the degree of obstruction and the situation of the growth. The improvement which may follow such a preliminary intervention is the best guide to the probable success of the major operation. Where the abdominal wall is directly invaded by an extension of the growth an elliptical portion of the whole thickness must be excised and care must be taken to secure a sufficient margin of healthy tissue beyond the edge of the growth. It may be difficult to repair the defect in the parietes completely but every endeavour must be made to provide at least a skin covering, even if it is necessary to raise a flap for that purpose. A considerable part of the wound may have to heal by granulation, and an incisional hernia will probably result, but that is the price the patient may have to pay for the chance of freedom from recurrence. When the *small intestine* is involved it is usually best to excise the affected coil completely, together with the colon growth, restoring continuity by end-to-end suture. When, on the other hand, the growth is involving some other portion of the *colon* by direct extension it may be perfectly safe and efficient to cut out a portion of the wall of the involved bowel to which the growth is adherent. This may leave a large window, but it can always be safely repaired. If the extension is to the lateral aspect of the large bowel or impinges on the mesentery, then nothing but a resection of the involved portion will suffice. The same considerations apply when the *stomach* is the organ invaded, and it will seldom be necessary to do a cuff resection, for quite a large portion of the stomach wall may be excised and comparatively easily repaired. When the *spleen* is concerned it is much wiser to excise the whole organ together with the growth. In the case of the *kidney* it is sometimes quite satisfactory to incise the capsule well away from the point where the growth is adherent. If the capsule can then be readily stripped from the kidney it is good evidence that the removal of the adherent portion of capsule is all that is necessary. When, on the other hand, the capsule will not strip, the kidney should be removed with the mass. Growths of the hepatic flexure sometimes involve the *gall-bladder* which can be excised with the tumour. When the *liver* is directly invaded, the affected portion may be removed by wedge-shaped excision, but if only the extreme edge is involved then it may suffice to slice off the affected portion (*see* p. 896). Single massive metastatic deposits and

strengthened by a series of interrupted Lembert sutures. The tube acts as a splint, and also as a channel for the passage of flatus and fæcal material; it is left *in situ* until the catgut sutures have absorbed. This method, though it appears simple and satisfactory, is not really easy to carry out. As a rule the lower end cannot be made to invert and the principle of intussusception often fails. The operation was originated by Rutherford Morison of Newcastle, and appeared to hold out great promise, but in practice it has not fulfilled these expectations and is now very seldom employed. Nevertheless, the writer believes that with a defunctioning colostomy it might suffice to approximate the bowel ends by means of the tube and to anchor them together with a few stitches here and there but without any attempt at invagination. If gauze were then packed round about the area and brought out of the lower end of the incision, healing would probably prove satisfactory.

In some cases the other alternatives may have to be adopted. The upper end may be fixed to the abdominal wall through a separate opening in the left inguinal region, and the lower end either sutured over and left behind or removed altogether, with the rectum and anus. The latter method is identical with the abdomino-perineal operation for excision of the rectum (Vol. II, Chap. XXIV).

Permanent colostomy with closure of the lower end.—The steps are the same as in the last operation up to the point where the growth has been cut away. If an inguinal colostomy has been made, the whole of the bowel below should be removed. If, on the other hand, a transverse colostomy or a cæcostomy had been undertaken preliminarily, a separate incision is made in the left iliac fossa as for inguinal colostomy, and through this the open upper end of the bowel is drawn and fixed to the edges of the wound. This open end, which will form a permanent artificial anus, may be temporarily closed, in order to prevent infection of the wounds by fæcal extravasation, or a Paul's tube may be tied in and immediate drainage instituted. The lower end—the divided rectum—is then closed by a double layer of continuous sutures, the inner layer passing through all the coats, the outer layer (sero-muscular) being used to bury the inner. The stump is then buried by sewing the peritoneum of the pelvic floor over it. Sometimes it is difficult to close this lower stump on account of its depth in the pelvis or the obesity of the patient. In either event it may be partially closed though not completely tucked in or oversewn. In any case it is essential to drain the rectum with a large tube through the anus. Probably a safer method is to pack iodoform gauze into the open rectum, one end being allowed to protrude from the anus. When possible the pelvic peritoneum is sutured over the gauze but this is not essential, though when it cannot be done the omentum should be packed into the pelvis over the gauze. At the end of the operation the anus should be well dilated. The gauze is removed piecemeal,

when borderline cases are included it may be 80 per cent. or even 90 per cent.

When the disease is complicated by obstruction the mortality is very considerably diminished by intervention in stages. So much does this apply that the writer is always glad to have an excuse for carrying



Fig. 466.—Carcinoma of the colon (A) involving a loop of jejunum (B) and a portion of the stomach (C). A two-stage operation, with triple resection and restoration of continuity, was followed by complete recovery. The man enjoyed good health for three years, and then died from another cause, without recurrence.

(*Reproduced by permission from The Lancet.*)

especially those limited to the left lobe have sometimes been dealt with by partial hepatectomy with some encouragement.* With the *pelvic viscera* the difficulties may be greater, for there is a tendency for the peritoneum of the pelvic wall to be involved over a considerable area. But even in these cases it is often possible to remove all the affected parts, though restoration of the continuity of the bowel may have to be omitted, a permanent colostomy being substituted.

Cases complicated by *vesico-intestinal fistulæ* are especially difficult as it is necessary to excise the portion of bladder surrounding the actual fistula and to remove it *en bloc* with the growth. Those situated high up on the posterior surface of the bladder can usually be readily managed. To make a clean sweep, an area of bladder wall about half an inch on all sides of the fistula must be removed. The bladder is opened at a convenient spot and the surgeon carefully cuts out the affected portion, using the scissors or diathermy knife. Sometimes the bowel growth is so bulky that it completely obscures the site of the fistula. In these circumstances it is best to separate the growth from the bladder and, with this out of the way, to deal with the latter unimpeded. Though this plan is not ideal it may be the best method of completing the operation. The defect in the bladder must be repaired by catgut sutures, taking a good hold and penetrating all but the mucous membrane. After these operations a large catheter must be left in the bladder *per urethram* and the pelvis should also be drained with a rubber tube, the patient being nursed in the Fowler position for the first few days.

Many of these extensive multiple resections do well, the patients surviving in comfort for years (Figs. 453, 466). Supposed recurrences are not necessarily always entirely unfavourable for an exploration; they may turn out to be excisable growths often limited to the colon. The writer has dealt with such cases in which the patient has enjoyed freedom from further recurrence for some years after a second colectomy.

Results.—Many factors influence the results of operations for cancer of the colon and, like all interventions for intra-abdominal malignant disease, the immediate mortality is often a reflection of the risk the surgeon is prepared to take in the hope of conferring the maximum benefit on his patients. With present-day methods of preparation, supportive care during operation, better anæsthesia and resuscitation it is possible to inflict a remarkable amount of surgical trauma without interfering with the recovery of the patient. But the benefit conferred must often be measured in terms of palliation and comfort rather than in length of survival. It is questionable whether the long-term recovery rates have been correspondingly improved. The surgical licence which modern methods confer must only be used with judgment and proper restraint, though to be too timid is the worst fault. The *resectability* rate in cases where there appears to be a good prospect of freedom from recurrence for some years is about 50 per cent., but

* Raven, *B M J*, 1947, ii, 249

a primary mortality of only 2·4 per cent. and an average hospitalization of just over 5 weeks.

TOTAL COLECTOMY

Multiple malignant growths, polyposis, multiple injuries such as may occur in warfare, compressed-air injuries and certain congenital anomalies like megacolon* may all require complete removal of the colon. It would also seem rational to consider the operation in those very acute varieties of ulcerative colitis in which the whole of the large bowel is involved and life is seriously threatened. It may be carried out in one or more stages, and the general condition of the patient, the necessity for bowel drainage and the disclosures of an exploration will determine which method is to be employed. In any event the operation is of considerable magnitude, and in all cases the patient should be properly prepared and a careful watch must be kept on the blood pressure and suitable measures adopted to anticipate shock. For the actual excision it is necessary to have a sufficient exposure, and usually a midline or left para-median incision extending from an inch or more above the umbilicus down to the pubes is satisfactory. The first step is to deal with the great omentum, which should be preserved whenever possible. In malignant growth in the transverse colon or at the flexures the part of the omentum in relationship to the neoplasm must be excised. In other cases the omentum should be turned up and its avascular attachment to the colon completely divided with the scalpel, close to the bowel. It is next necessary to mobilize the colon by dividing the membranous bands and adhesions on its outer side. These are much more fully developed about the cæcum, hepatic flexure, splenic flexure and sigmoid, and they should be systematically and freely divided under the guidance of the eye. When there is no question of malignant disease, the division may be made close to the bowel in order that the exposed retroperitoneal area which will be left may be as small as possible. In many of the bands there are vessels, and though none of these may individually account for much hæmorrhage, in the aggregate a considerable loss of blood may occur unless they are caught and ligatured. It is therefore best to clamp the bands with artery forceps before dividing them and to take care to apply ligatures in every case. After mobilization in this way the colon can readily be separated from the extraperitoneal tissue by gauze stripping and thrust gently towards the centre of the abdomen. This having been done, the next step is to divide the mesenteries and secure the main vessels. These structures may be dealt with before the bowel is cut across, or the division of the ileum may be regarded as the most convenient method of approaching the mesentery, from which point the control of the vessels may be commenced In thin subjects the first method is quite easy and

* One such patient, in whom the end of the ileum was anastomosed to the rectum after total colectomy, is alive in good health and working regularly 41 years later. He takes ordinary food; the bowels are moved four times daily

out preliminary bowel drainage and completing the excision at another stage. Growths that have invaded the parietes or neighbouring viscera are always more difficult to deal with but, given a patient who has been adequately prepared, even multiple resections are not in themselves especially dangerous. Whatever the method employed, it is necessary to exercise punctilious care in carrying out the operative details and the whole intervention must be conducted under the guidance of the eye. It is significant that those cases in which the growth has been complicated by abscess formation often do well.

Up to the end of 1931, the writer had operated on 279 malignant cases; in 165 the growth was excised with an overall mortality of 18 per cent. In 107 cases operated upon since 1919 the mortality was 14 per cent. In 147, continuity of the bowel was restored, and in 18 after resection the patient was left with colostomy. The series included many double and complicated resections.

The after-histories of 115 of the cases were reviewed; 41 died of recurrence within 5 years, and 64 were alive or had died without recurrence at periods up to 15 years after operation. In Lockhart Mummery's series, 41 cases were operated upon more than 5 years previously and of these 20 were alive and free from recurrence. Out of 42 cases traced by Sir Charles Gordon-Watson 15 were alive and well over 5 years. It is probable that 60 per cent. of those surviving the radical operation will be alive and well 5 years later. Generally speaking the outlook is rather better for right-sided growths.

When all cases both with and without obstruction and other complications are included an average mortality of 10 per cent. probably reflects the results of any group of experienced surgeons to-day. If that could be reduced to 5 per cent. in a considerable series, including all parts of the large bowel and all types of case, it would certainly represent sound judgment. Some surgeons have attained even better success in fortunate runs of operation, but they are unlikely to continue to enjoy such comforting rewards as the number of their cases increases. The writer has more than once set out with the determination to carry out a century of colectomies without a death, but after encouraging runs of successes one or more deaths, sometimes occurring consecutively, have marred the record. In the near past probably the extra-abdominal method proved the safest so far as immediate results are concerned, but there are operable cases for which it is not suitable and in a good many cases the after-result is spoilt by local recurrence in the abdominal wall. Some indication of the *operative mortality* of this method is furnished by the following figures Gordon-Taylor up to 1941 had a series of 138 extra-abdominal excisions with only 7 deaths During the last few years both mortality and morbidity have been much reduced as the result of better preparation, the use of prophylaxis against infection, and better anæsthesia technique and after-care. Allen* during the period 1945 to 1949 reported 129 cases with a resection rate of 96 per cent. and

* Allen, A. W., *Annals of Surg*, 1951: 134, 785

slavish attempt must be made to drag parts together at great tension, and especially does this apply to the cut mesentery with its vessels. If peritoneal edges cannot be readily approximated they can often be partially drawn over bare areas and then fixed to the posterior abdominal wall with an odd stitch here and there. As a last step the omentum should be drawn down over the small intestine. The abdomen is closed without drainage.

Arbuthnot Lane used to lay stress on the importance of passing a tube from the anus up through the anastomosis into the small intestine, but this is often difficult to accomplish and of doubtful advantage. It is useful to leave a tube through the rectal sphincter to guard against the accumulation of flatus.*

Hirschsprung's disease and megacolon.—As the result of close study of these and other allied conditions, it is now recognized that there are several types, as there are certainly different stages at which patients may come before the notice of the surgeon. Whatever the initial lesion cases may present with more or less acute obstructive symptoms, with chronic impaction or its sequels or with obstinate constipation, increasing distension and general undermining of health and comfort.

The differential diagnosis as to the type and cause of the condition may suggest and justify different methods of treatment. But, whatever the cause, if there is marked obstruction, colostomy may be required as a temporary measure or to assist a medical regimen.

Recently attention has been focused on the condition in young infants and children and many valuable observations have been recorded.†

As a result of this work it was found that, in a high proportion of cases, the primary lesion was located in the region of the recto-sigmoid junction and was a congenital aplasia of ganglion cells, explaining the lack of co-ordinated propulsive movement in this region of the bowel. Many of these cases were successfully treated by recto-sigmoidectomy.

There are other cases, seen later in life, where medical management has completely failed, or where previous operations like sympathectomy have not given lasting relief, or where colostomy has become a nuisance or an embarrassment.

In these circumstances colectomy, partial or complete, may be indicated. Operation should not be undertaken unless the colon has been decompressed or even emptied and this also may require preliminary colostomy. Further, there must also be adequate preparation on the lines already indicated (p. 1083). As a first step, if the whole colon is to be excised, any existing cæcostomy or colostomy must be temporarily closed and that part of the bowel detached from the abdominal wall. For partial colectomy on the left side, or

* When the pathological conditions are such that part of the lower sigmoid can be retained the operation may be completed by the Paul Mickulicz plan

† (a) Bodian, Stephens & Ward, *Lancet*, Jan 7th, 1950, (b) Douglas Stephens, *Annals R.C.S.*, vii, 4, Oct., 1950

satisfactory but the mesentery of the corpulent may be more safely approached by the second plan.

It is not necessary to detail the various methods by which the vessels may be secured, but it is important to emphasize the risk of overlooking a vessel which may quickly retract and bleed when divided. Every bit of mesentery should be included in the ligatures and a sharp look-out must be kept for what may appear to be tiny vessels which might escape. If the method of transfixion is used care must be taken not to puncture vessels. The instrument used should have a blunt point and should be made to worm its way through the mesentery rather than be quickly thrust through. The mesentery may be caught and divided close to the bowel, but the amount of tissue to be ligatured can be diminished by securing the vessels some little distance away from the edge of the bowel. When the mesentery is very fat, vessels easily retract and in that way escape ligation; to avoid this accident the tissues should be cut at least half an inch beyond the point at which the ligature is to be applied and it should be securely tied before the artery forceps or clamp is removed, though the latter should be carefully loosened in order that the ligature may secure a better bite. If hæmatomas form in the mesentery they must be investigated at once (*see* p. 1057).

When the second method is adopted, the ileum is divided about six inches above its termination and, having protected the open ends, the surgeon proceeds systematically to clamp and divide the mesentery right round until the sigmoid is reached. The amount of sigmoid to be removed will depend on the pathological condition but, generally speaking, the more sigmoid that can be preserved the better will be the functional result. The vessels having been carefully ligatured and all potential sources of bleeding systematically considered, the continuity of the bowel can be safely restored by making an axial anastomosis between the open end of the ileum and the sigmoid. This should present no difficulty, and is certainly as safe and satisfactory as a lateral or side-to-side union. If the latter has already been made at a first operation, it is only necessary to divide the ileum and sigmoid, and securely tuck in the ends, care being taken not to leave long blind culs-de-sac beyond the point of the anastomosis.

If a preliminary cæcostomy or colostomy has been made, the first stage of the intervention should take the form of a rough closure of such an opening. This can be done by making an incision through the skin around the fæcal fistula about ½ in. from its margin and undercutting the skin to form a fringe which can be tightly sutured over the fistula This having been done, the adjoining bowel must be *freely separated from the parietes and returned to the abdomen*, after which the operation is conducted as in an ordinary case. The defect left in the abdominal wall at the site of the cæcostomy must be sutured in layers, either there and then or as a last stage in the operation. When the anastomosis has been completed, all areas denuded of peritoneum should be covered as far as possible. No

An illustrated description of the operation will be found in the *Annals of the Royal College of Surgeons* (*loc. cit.*).

Ulcerative colitis.—In operations for ulcerative colitis it is important to remember that the ulcers are multiple and that very often they are on the point of perforation, so that any but the gentlest handling may precipitate this calamity. Total colectomy has sometimes been recommended for the very acute fulminating type of this disease. In these circumstances the ileum must first be divided, the upper end being fixed in the wound as a terminal ileostomy which usually has to be permanent. The large bowel is then removed as already described. Previous investigation will have disclosed the condition of the rectum and lower sigmoid. When the disease is not very well marked in these parts the division should be made in the lower part of the sigmoid, in the hope that at some subsequent time the ileum may be united to this part of the bowel to restore the continuity of the canal. Any residual ulceration in the sigmoid or rectum may heal as the result of physiological rest, and in any event, can be suitably treated *per rectum*. On the other hand if it does not yield to proper management what remains of the sigmoid and the rectum may be excised by the abdomino-perineal route. This staged excision has proved safer than total colectomy in one sitting.

Ileostomy.—At the present time for cases of lesser severity ileostomy is most in favour as a means of excluding the seat of the disease and providing physiological rest for the colon.* Those with most experience of this troublesome disease are in favour of much earlier surgical intervention than has usually been practised.

The simplest method is the *loop enterostomy* in which the intestine is brought through a small incision in the right iliac region, either of the gridiron type or a muscle cut or a short paramedian incision. A loop of healthy ileum about 6 in. from the cæcum is withdrawn; the loop must not just be blindly hooked up into the wound but its relation to the cæcum verified by identification of the fold of Treves. The loop is fixed in the incision with a few sutures, or a rod passed through the mesentery, and is opened on its summit or is divided across. A large rubber catheter is introduced into the proximal gut and fixed by a purse-string suture or it will be expelled by peristalsis. When the bowel is divided the opened end of the distal segment is closed with a crushing clamp or a stout silk ligature which remains *in situ* until the parietal incision is healed.

Terminal ileostomy.—In this more satisfactory method the ileum is cut across and either both ends are brought out side by side, a tube being tied into the proximal end, or the distal end is closed by suture and returned to the abdomen or brought out through a separate button-hole incision and occluded by a clamp or silk ligature.† This method of ileostomy provides a more certain and effective exclusion of the colon. When the catheter loosens and is extruded after about

* R S Corbett, *Proc R.S M*, xxxviii, 277
† Cattell, *Surg Clin. N America*, 1939, xix, 629.

recto-sigmoidectomy, it is better that any such colostomy should be left as a safeguard until some weeks after the excision.

Both complete and partial colectomy are quite straightforward, though the mere size and bulk of the bowel may make it rather awkward to handle.

It is tempting to complete the operation in one stage by intra-abdominal anastomosis, but the Paul-Mickulicz method is undoubtedly safer. The operation can be suitably modified by completing two-thirds of an end-to-end anastomosis by suture and leaving the remainder open as a temporary colostomy at the site of the anastomosis, the edges of the unsutured area being fixed to the margins of the parietal incision at skin level. This sort of modified colostomy tends to retract and may close spontaneously when the bowels commence to function naturally *per rectum*, though it may have to be closed by suture.

When the condition also involves the rectum the division of the bowel may have to be made through the distended part which will subsequently recover as the result of persistent watchful management. In these operations there is much scope for judgment and experience.

Recto-sigmoidectomy.—In infants preparation is most important and the first essential is to empty the distended colon. This will require repeated irrigation with possibly digital and bimanual removal of fæcal masses. The general health also requires careful attention.

Preliminary colostomy is next made into the transverse colon, above the site where the abnormality seems to start. There must be a good spur and the bowel should be stitched to the parietal peritoneum to lessen the tendency to prolapse.

Thereafter care is taken to completely empty the distal segment of colon. When this has been accomplished and the general condition has sufficiently improved the recto-sigmoidectomy is proceeded with. This is a simultaneous abdomino-perineal operation. The abdomen is explored and the site of division of the affected bowel is carefully selected and marked, but is not actually divided until later. It is usually at the pelvic brim or through the sigmoid or pelvic colon. The bowel is freed from above, the rectum being cored out of its muscles and supporting tissues. The bowel to be removed is then prepared to be intussuscepted, through the anus. The peritoneal pelvic floor is repaired from above. The remainder of the operation, except for the closure of the abdominal incision, is carried out from below. The part to be removed is prolapsed outside and cut away at the point previously selected from above and the anastomosis is made outside the anus. The stump of rectum and anal canal is returned through the sphincter to its normal position. About two weeks later the colostomy is closed. The operation is rather severe for young infants but Douglas Stephens had only three deaths in 27 cases. The results are said to be very good from the functional point of view and it is predicted that they will be much better and more uniform than by the other methods which have been used.

important and will require knowledge and resource on the part of the surgeon who is fortunate if he can share responsibility with an understanding physician.

The mortality of all operations for the ulcerative type of colitis is high but would improve if surgical measures were carried out at an earlier stage. Complications are not infrequent, especially connected with perforation, such as peritonitis, abscess and fistula; intestinal obstruction also occurs.

Appendicostomy.—This aims at providing a ready means of irrigating the colon and has from time to time enjoyed much popularity in the treatment of colitis. Among careful surgeons the method has been recognized as a useful adjunct in the management of this troublesome disease but is now rarely employed, ileostomy being more frequently carried out. (For technique, *see* p. 1040.)

Multiple polyposis.—The only reasonable treatment is removal of the involved bowel. When malignant disease has already supervened this must be very complete and will almost certainly mean total colectomy. If the condition is still in the adenomatous stage probably the best plan is first to deal with any polypi within reach of the operating sigmoidoscope and then to deal with the bowel higher up as the conditions demand and at another stage. In any event the condition may be attended with so much, or such continuous, hæmorrhage from the bowel that there is intense anæmia. If this does not respond to preparatory measures, including, of course, the full resources of blood transfusion, it is essential that the operative treatment should be carried out in stages. As a first step a cæcostomy or, in very bad cases, terminal ileostomy is carried out. After the full benefit of physiological rest has been secured, which may only be after some months, the second stage may be carried out. This consists of removal of the bowel from the point where the ileum was divided to the lower sigmoid. The site of division of the latter will depend on the location of the polypi in the pelvic colon as determined by previous investigation. The last stage consists in the restoration of the continuity of the bowel. This may be done either by making a lateral union between the ileum a short distance above the ileostomy and the remaining pelvic colon or by detaching the ileum at the enterostomy from the abdominal wall and making an end-to-side anastomosis with the lowest part of the pelvic colon. When the method of lateral anastomosis has been used, a further stage consists in the excision or closure of the ileostomy. Where there are great aggregations of polypi in the rectum and pelvic colon it may be necessary to remove those portions of bowel as in the abdomino-perineal method of excision of the rectum. This would mean either an anal ileostomy or a permanent ileostomy and only the gravity of the subsequent development of malignant disease in the remaining polypi can justify such a step.

Removal of single polypi.—These adenomata are usually of considerable size, perhaps anything from ½ in. to 2–3 in. in diameter. The larger

a week the fluid intestinal contents escape more or less continuously to be delivered into a suitable apparatus of which several varieties are available.

There is a tendency to irritation or excoriation of the skin which must be protected by one of the aluminium pastes or an adhesive bag. A small dose of ferrum redactum, as much as will lie on a sixpence (5 grains), taken after each meal, is said to render the intestinal contents much less irritating. After a few months the effluent becomes semi-solid and is much more easily dealt with. The general condition improves and most patients can resume work and are reasonably contented, although it must be admitted that the psychological make-up of the patient has a good deal to do with the result.

In the few cases in which the colon completely recovers, the continuity of the canal may be restored. Even in the most favourable circumstances restoration should not be attempted sooner than six months to a year after the enterostomy and there must be good evidence that healing of the large bowel is complete. The necessary intervention is no trivial proceeding and demands considerable care. The requirements are to separate the open intestinal ends from the parietes, to divide the bowel cleanly across above and below and to make a formal end-to-end anastomosis. Where the distal end of the ileum has been deliberately closed or has very much contracted or is very short, the union may be made end-to-side into the cæcum or by lateral anastomosis after closure of the end of the divided ileum.

When the colon does not recover it may be considered wiser to remove a source of infection and annoyance by colectomy as described.

Abdomino-anal ileostomy.—Recently the method of abdomino-anal ileostomy has been revived. This is a combined operation and may be carried out by three methods. First by dividing the rectum below the level of the peritoneum, everting the lower end through the anus after dilatation and making an anastomosis to the ileum which is drawn through the anus to the exterior. After suture the anastomosis is withdrawn upwards into the normal position of the rectum. Secondly the mucous membrane may be removed from the fragment of rectum and the divided ileum pulled through and fixed with a few sutures to the anal margin, or thirdly the ileum may simply be pulled through the rectum and anus without excision of the mucous membrane. In both cases the redundant part of the ileum will necrose and disappear

It is said that in about 50 per cent of the cases the result has been functionally satisfactory but if not so the ileostomy can be remade so that the attempt at restoration is not irreversible. But except perhaps in the fulminating type of case none of these operations should be undertaken without adequate preparation Patients who are considered for this operation are usually very ill and in poor condition and malnutrition, vitamin deficiency, infection, anæmia and general disturbances of metabolism must all be supervised and treated while the morale of the patient is sustained After-care is also most

intestinal obstruction while in other cases the symptoms are more of local inflammatory trouble, often with sinuses or fæcal fistulæ over the site of the disease. In either case the patients are often in poor condition. None the less, the disease is usually localized, and the results of surgical removal have been encouraging. It is most important that the patient should be properly prepared, by attention to sepsis and anæmia; blood transfusion and streptomycin will both be valuable. In most cases a two-stage intervention is best and this should take the form of a preliminary short-circuit. When there is no marked obstruction the ileum should be divided above any obvious disease, usually about a foot away from its termination. The lower end is completely closed while the proximal end is joined to the colon beyond the hepatic flexure by the end-to-side method. On the other hand, if the ileum is much distended a lateral anastomosis to the colon is safer.

Occasionally, so much benefit follows the relief of the obstructive symptoms that further intervention is not indicated. When there is a considerable mass, especially if associated with outbursts of pyrexia, or there are sinuses or fæcal fistulæ, the best hope lies in a well-planned excision. For this second operation emphasis must be laid on the advantages of an incision directly over the affected site (Fig. 467), for only in this way is it possible to deal with the fixation under the guidance of the eye. If there are sinuses or fistulæ these should be excised with an ellipse of the abdominal wall which can be readily included in the oblique incision recommended. As a rule the lymph nodes in the ileo-cæcal angle are invaded with tubercle and it is much wiser to remove them together with the bowel. If an anastomosis has not already been made, the ileum should be divided about a foot above the cæcum and the ileo-cæcal angle removed, together with the cæcum, ascending colon and hepatic flexure. In making the anastomosis there must be no blind end to the ileum, as this is apt to harbour tubercle bacilli with the development of secondary fæcal fistula. Direct end-to-end union of the ileum to the colon is best, but if the ileum has already been divided and joined to the colon the latter should be divided and tucked in close to the anastomosis in order to avoid a cul-de-sac.

After operation it is necessary for the patient to have a long period of convalescence under the best conditions that can be provided, so that any residual tubercular disease may become quiescent and eventually heal. This period has to be counted in months rather than weeks, and convalescence of from six months to a year is certainly not too long for the purpose.

Impaction of foreign bodies.—The only foreign body likely to be met with is an impacted gall-stone, and this is exceedingly rare in the large bowel. When it does occur it is nearly always in the sigmoid, but calculi so enormous as to become arrested in the transverse colon have been known.* In some cases the condition has been diagnosed as

* Grey Turner, *Brit. Journ Surg.* 1932, No. 77, xx, 26.

polypi often have very short stalks and are almost sessile, in which case it is much wiser to excise the portion of bowel in which they arise, and this especially applies to those cases in which the growth is on the mesenteric side. The smaller polypi, on the other hand, usually have quite long stalks, and in these circumstances they may safely be locally removed. The portion of bowel in which the polypus is arising is withdrawn from the abdomen, which is packed off. The lumen is then opened by incision along the anti-mesenteric border over the site. With the incision in the bowel held well open, the polypus and its attachment may be withdrawn from the interior so



Fig. 467.—Incision for removal of cæcum for tuberculosis.

that the base is well exposed. An ellipse of mucous membrane is then excised, together with the base of the stalk. After the mucous membrane is incised all round, it will be necessary to apply a ligature to the vessels entering the stalk and then to repair the bowel wall with a few interrupted sutures, taking a good hold of the submucous tissue as well as the mucous membrane. The outer aspect of the bowel opposite the point of attachment must be inspected and if necessary protected by the insertion of one or two Lembert sutures. The incision made into the bowel for the exposure of the polypus must be repaired in the transverse axis so that there can be no question of diminishing the lumen.

Tuberculosis.—The only condition in which operative intervention is likely to be called for in this disease is in the so-called massive tuberculosis of the cæcum This is sometimes associated with chronic

CHAPTER XXII

OPERATIONS FOR APPENDICITIS AND PERITONITIS

By G. GREY TURNER

I. APPENDICITIS

INFLAMMATION of the appendix vermiformis is responsible for the large majority of acute abdominal conditions, and in its subacute or chronic phases it may give rise to many forms of ill-health. The usual tendency in appendicitis is towards recurrence. Between attacks patients may be perfectly well, or may suffer in various ways, e.g. indigestion, abdominal pain, chronic toxæmia. As the result of recurring inflammation a stricture may form in the wall of the appendix, leading to retention of secretion in the distal end; or the walls may become thickened and the lumen stenosed. Adhesions to neighbouring structures may cause much trouble. There is also evidence of some relation between the pyloric sphincter and the ileo-cæcal valve, and chronic inflammation of the appendix may have a causal relationship to pyloric spasm and to duodenal ulcer.*

The appendix is also subject to certain diseases, such as tuberculosis, actinomycosis, and adeno-carcinoma, and may be secondarily affected in peritonitis originating elsewhere. Threadworms are not infrequently present in its lumen, sometimes giving rise to a subacute type of infection, and roundworms may cause acute gangrene. Foreign bodies (such as shot or bristles) are found occasionally, and fæcal masses (enteroliths) are common, the latter possibly determining perforation in some acute infections.

An acute appendicitis may follow several courses If drainage from the lumen into the cæcum is satisfactory, the inflammation may resolve; if there is indifferent drainage, the appendix may become distended with pus and burst, causing gross infection of the peritoneum in the vicinity or diffuse peritonitis Should the infection be very acute, gangrene and sloughing of the appendix may occur, or the vessels in the meso-appendix may become thrombosed and be the cause of portal pyæmia. In a less virulent infection the inflamed appendix may become wrapped in omentum or walled off by adhesions, so that if an abscess occurs it may, for a time at least, be definitely localized

The anatomical position of the appendix has an important bearing on its surgical management. For the most part the organ lies in the sulcus on the outer side of the cæcum directed either laterally or medially. In a certain proportion of cases it lies behind the cæcum so that the consequences of inflammation are apt to be hidden. When there is suppuration, the abscess may extend behind the colon for a

* Braithwaite, L. R., *Brit Journ Surg.* 1942, No. 117, xxx, 15.

obstruction from new growth and has been treated by cæcostomy in the first instance, which is probably the best thing that could happen. For the actual removal of the calculus an incision has to be made along the longitudinal band over the site of the gall-stone, and this should be long enough to allow the calculus to be removed without damaging the wall of the bowel. This incision must then be sutured in the opposite direction in order to diminish the narrowing of the bowel which might otherwise occur

Partial colectomy for diverticulitis.—When this is required it is usually the sigmoid or pelvic colon which is affected. The operation is undoubtedly much safer if it is done as a second-stage intervention after preliminary bowel drainage, usually colostomy of the defunctioning type. The technique required is in general the same as in operations for new growth but is often a great deal more difficult, for there is usually much more local inflammatory fixation which complicates the mobilization. Small abscesses may also be encountered. It is not necessary to make any wedge-shaped excision of the corresponding mesentery, although it is well to remove enlarged lymph nodes which might harbour infection. The actual anastomosis should be carried out at a point free from diverticula but this is not always easy to determine, especially when the colon is loaded with fat. In these circumstances it is a good plan to dissect away the fat from not more than half an inch of either bowel end and expose hidden diverticula. Should a diverticulum be encountered when making the division of the bowel, great care should be taken to remove it before the bowel is sutured. This may entail a considerable dissection and may lead to some irregularity in the margin of the bowel, but this is of much less moment than the risk of leaving part of the lumen of a diverticulum exposed to the peritoneum. The anastomosis should be most carefully protected with the adjoining appendices. When there is a communication with the bladder, the bowel is separated from that viscus and the fistula in the latter closed by suture. This may not be easy on account of inaccessibility or because the bladder wall is much indurated about the margins of the fistula. In these circumstances the aperture may be plugged with omentum or neighbouring fat stitched over. In any event the bladder should be drained by catheterization or temporary cystostomy and the pelvis by a rubber strand or softened tube It is wise to pass a large tube through the anal sphincter and leave it *in situ* for at least four days. During this time the patient should be nursed in the Fowler position and great care should be taken to ensure that the bladder is kept empty. Diverticula of the cæcum are not so uncommon as was formerly thought,* and are often associated with inflammatory trouble, simulating appendicitis and sometimes new growth. A single diverticulum may sometimes be excised but when multiple or complicated hemi-colectomy is usually indicated.†

* Shaw and Siegler (1950) *Lancet*, Jan 21, p 114
† Grey Turner (1905) *Lancet*, Sept 16

Some of the most difficult problems in diagnosis are met with *in acute diseases of the chest* causing abdominal pain and rigidity. Attention was first drawn to these cases in Great Britain by the late H. L. Barnard* and the condition is now well recognized and often discussed, but errors still occur. The chest complaint was often overlooked and an operation for a supposed acute appendicitis carried out. Now, the possibility of error is so appreciated that the tendency is to diagnose as acute chest conditions what are really acute abdominal conditions, and thus to miss the chance of early intervention. A rectal examination may be very valuable, and is so important that no abdominal examination should ever be considered complete without it.

Among other conditions which must be differentiated from acute appendicitis in children are pneumococcal or acute tuberculous peritonitis, an acute gastric upset, intussusception and other forms of intestinal obstruction, and Henoch's purpura. An appendix abscess in a child may cause flexion of the hip and lead to a diagnosis of joint disease. The most difficult disorder to differentiate from chronic appendicitis in children is tuberculous disease of the mesenteric glands. (*See* p 1155.)

Acute Appendicitis

Indications for operation.—The view widely held, that operations should be carried out as soon as an acute appendicitis is diagnosed, has everything to commend it, but, like all generalizations, has been subjected to much criticism. That the mortality of acute appendicitis increases steadily with delay in operating is undoubtedly true, and if all cases could be operated upon while the disease is still limited to the appendix or its immediate neighbourhood, many lives would be saved. But many cases are not seen until perhaps the severity of the attack is beginning to decline, and it is then that difficulties in diagnosis occur and differences of opinion arise over proper management.

The late Professor Sir David Wilkie of Edinburgh drew attention to what he considered the essential difference between acute obstruction of the appendix, which is so likely to lead to gangrene with its consequences, and primary inflammations which often go on to resolution or to localized abscess. He suggested that in the first group operation is imperative, while in the second the surgeon may often stay his hand until a convenient opportunity. While this distinction is of much academic interest, it is apt to be dangerous as a guide to management, for nothing should be allowed to countenance delay in operating. Another school is largely guided by the time which has elapsed after the onset of an attack. They measure pathological progress by the clock and make it a guide to treatment. These surgeons advocate delaying operation in all cases that are not seen until 36 hours after the onset. It is claimed that the majority then safely subside and localize and that the delayed operation is attended by a lower mortality, a lessened incidence of complications,

* *Lancet*, Aug. 2nd, 1902.

considerable distance, and may even come in contact with the second part of the duodenum, into which it has been known to discharge. When the appendix lies on the outer side of the cæcum and is directed upwards, the inflammatory products may collect in the right loin pouch (Morison's pouch, *see* p. 872), and may impinge on the under aspect of the right lobe of the liver, or may creep over the upper surface of that organ. When the organ lies in the opposite direction it may reach the pelvic brim or hang over it, and may even touch the bottom of the recto-vesical or Douglas's pouch. In other cases it may lie along the ileum, or it may pass up behind that part of the small bowel, so that its tip points into the midst of the small intestine area.

When in the pelvis, the products of the inflammation may localize there or may overflow into the abdomen. In the latter event the tendency is to spread *via* the sulci on the outer side of the colon, either into the right loin pouch or the corresponding position on the left side, and from either situation the path to the liver and spleen pouches is usually unimpeded. In other cases the infection may directly invade the small intestine area from the pelvis, and when that occurs a general peritoneal infection almost certainly follows. From this it is seen that general peritonitis is very probable when the inflamed appendix lies in the small intestine area. The base of the appendix is the only part of the organ which can be said to have a more or less fixed position, and is indicated by McBurney's point.

The *age* of the patient and *the recurrence or otherwise of previous attacks* influence the course of the disease. *Diffuse* peritonitis is generally more common as the result of the first attack. If recovery takes place there will certainly be further attacks at gradually shortening intervals. Any one of these attacks may be severe, but the general tendency is a decrease in severity though the attacks become more frequent The influence of age may be summarized in the formula, "The younger the patient the graver the disease"

In children the appendix is relatively large and its walls, especially the submucosa, are thin, so that perforation occurs rapidly; there is less tendency to localization, partly because the inflamed appendix is more often found among the intestines in children than in adults, and also because the peritoneum is less resistant. In addition to these facts, the diagnosis of appendicitis, and particularly the differential diagnosis, is much more difficult in children Attacks of colicky abdominal pain are common in early life, vomiting is not infrequent, and pyrexia is an uncertain guide. Children under 10 years of age or so have little sense of localization of pain, and all abdominal pain is referred to the umbilicus, but intelligent observation will discover that the most marked tenderness is over the seat of the appendix. Even in pelvic appendicitis, tenderness can nearly always be elicited low down by the side of the right rectus muscle, and young children will often accurately indicate the site of tenderness if they are encouraged to cough

Some of the most difficult problems in diagnosis are met with *in acute diseases of the chest* causing abdominal pain and rigidity. Attention was first drawn to these cases in Great Britain by the late H. L. Barnard* and the condition is now well recognized and often discussed, but errors still occur. The chest complaint was often overlooked and an operation for a supposed acute appendicitis carried out. Now, the possibility of error is so appreciated that the tendency is to diagnose as acute chest conditions what are really acute abdominal conditions, and thus to miss the chance of early intervention. A rectal examination may be very valuable, and is so important that no abdominal examination should ever be considered complete without it.

Among other conditions which must be differentiated from acute appendicitis in children are pneumococcal or acute tuberculous peritonitis, an acute gastric upset, intussusception and other forms of intestinal obstruction, and Henoch's purpura. An appendix abscess in a child may cause flexion of the hip and lead to a diagnosis of joint disease. The most difficult disorder to differentiate from chronic appendicitis in children is tuberculous disease of the mesenteric glands. (*See* p. 1155.)

Acute Appendicitis

Indications for operation.—The view widely held, that operations should be carried out as soon as an acute appendicitis is diagnosed, has everything to commend it, but, like all generalizations, has been subjected to much criticism. That the mortality of acute appendicitis increases steadily with delay in operating is undoubtedly true, and if all cases could be operated upon while the disease is still limited to the appendix or its immediate neighbourhood, many lives would be saved. But many cases are not seen until perhaps the severity of the attack is beginning to decline, and it is then that difficulties in diagnosis occur and differences of opinion arise over proper management.

The late Professor Sir David Wilkie of Edinburgh drew attention to what he considered the essential difference between acute obstruction of the appendix, which is so likely to lead to gangrene with its consequences, and primary inflammations which often go on to resolution or to localized abscess. He suggested that in the first group operation is imperative, while in the second the surgeon may often stay his hand until a convenient opportunity. While this distinction is of much academic interest, it is apt to be dangerous as a guide to management, for nothing should be allowed to countenance delay in operating. Another school is largely guided by the time which has elapsed after the onset of an attack. They measure pathological progress by the clock and make it a guide to treatment. These surgeons advocate delaying operation in all cases that are not seen until 36 hours after the onset. It is claimed that the majority then safely subside and localize and that the delayed operation is attended by a lower mortality, a lessened incidence of complications,

* *Lancet*, Aug 2nd, 1902.

and a shorter stay in hospital. Most cases of appendicitis require operative treatment, but the urgency varies and whereas in very acute, rapidly progressing cases the surgeon "must know no night no day", there are others in which convenience may play a part in deciding when the operation should be performed. Again there are cases, especially with abscess formation, in which the patient is so profoundly toxic or suffering so much from acidosis that a delay of some hours is absolutely essential in order that these conditions may be combated. There are also many desperately ill cases with unlimited peritonitis, in which the extent of the intervention and its technique must both be modified, and in such the mere incision of an abscess under local anæsthesia may be life-saving, whereas a classical operation with a search for the appendix may be fatal. It must always be remembered that simple drainage will often save life and that the appendix can be safely left for subsequent removal.

For many years the writer has found it convenient to classify cases in the following groups:—

Group 1: Acute appendicitis without peritonitis.
Group 2: Acute appendicitis with localized peritonitis.
Group 3: Acute appendicitis with flank or pelvic peritonitis, or both.
Group 4: Acute appendicitis with diffuse peritonitis
Group 5: Appendicitis with residual abscess.
Group 6: Appendicitis with primary localized abscess.
Group 7: Appendicitis—interval removals.
Group 8: Appendicitis with primary complications.
Group 9: Appendicitis—no operation.
Group 10: Appendicitis—incidental removals.

There is no classification of appendicitis that is not open to error and to which objections cannot be raised, but this simple grouping has proved both useful and practical. The basis of the classification is a pathological one. The disease, starting in the appendix, spreads as a radiating infection and in the great majority of cases at its inception it is entirely local.

Groups 1 and 2 would naturally include the very early cases, that is to say, those seen probably within 12 to 24 hours

Group 3 includes patients who may have only been ill for perhaps 24 hours, but with the same extent of inflammatory extension other patients may give a history of an illness extending over a period of 2–3 days.

Group 4 would ordinarily be looked upon as only a later stage of group 3, but that is not always in accordance with what actually happens, for the acuteness of the inflammation and the rate of invasion of the peritoneum vary very considerably.

Group 5 was introduced for a class of case which is not often encountered at the present time, but which used to be quite frequent some years ago when the need for early surgical intervention was not so well recognized as it is to-day. Such patients usually give a history of

having passed through an attack of general peritonitis and reached a stage in which recovery has come to a standstill. In these circumstances it is not uncommon to find a collection of pus in the pelvis, in one or other flank, or between the coils of the small intestine. Such abscesses have to be distinguished from those that remain localized about the appendix wherever that organ happens to be situated. These latter cases form group 6. The cases included in group 7 are those in which there is no active inflammatory trouble but in which the evidence of a lesion in the appendix is unmistakable. Sometimes they are spoken of as "interval" or "cold" cases. From the operative point of view they are in an entirely different category from all the others and for that reason their management is considered separately.

Group 8 is introduced to include cases where the acute appendicular mischief is complicated by such conditions as portal pyæmia (pylephlebitis), intestinal obstruction or some acute chest mischief.

For groups 1, 2 and 3 there is now general agreement that immediate operation is the only proper course. None the less, there are cases in which the symptoms so rapidly improve that the question of deferring the operation may be raised, but this is dangerous. Even when an attack does safely subside, there is an invariable tendency to recurrence, and therefore the surgeon must always urge that the evil day is only being deferred and that the next attack may come on at a much more inconvenient time.

In group 4, though some type of operation is demanded, there may be very good reasons for deferring the intervention for some hours to institute treatment directed to improve the general condition. In these cases the patient may be so desperately ill that the scope of the operation may have to be limited and mere incision over the appendix region for drainage may be the only measure permissible in the hope of saving life.

In group 5, again, an operation is usually required, but only for the evacuation of the abscess wherever it may happen to be. In the majority of cases in this group removal of the appendix must await a later intervention when all signs of active inflammation have subsided.

In group 6, even with the help of chemo-therapy, operation is nearly always essential, but the scope of the intervention may be varied. On many occasions it may be possible to open the abscess and to remove safely a very accessible or easily-found appendix, while in others it may be very much wiser merely to drain the abscess in the first instance, leaving removal for later intervention during a quiescent period after the lapse of three or four months. During this waiting period it is not necessary for the patient to remain an invalid, but he must be warned that, should there be any recurrence of pain or other evidence of activity, immediate surgical intervention may be required The greatest difficulty occurs in those cases in which the severity of the symptoms is waning when the patient is first seen and there is only a slightly tender but extremely hard mass in the iliac fossa In such cases there has probably been an appendix abscess

which has leaked into the bowel or in which the subsiding inflammation has been followed by the development of very dense inflammatory tissue, perhaps enclosing a collection of inspissated pus. In this group it is best to keep the case under observation and, if *all* the symptoms are improving and the mass is gradually disappearing, it is well to continue to defer operation until there is nothing but remaining tenderness to indicate the pathological change which has been present. This will usually necessitate a delay of from four to six weeks.

Group 8 will always demand the earliest possible intervention but the prognosis will depend more on the associated complication than on the condition of the appendix.

Appendicitis in children and in the aged.—In the very young and in elderly individuals inflammation of the appendix is a matter of extreme urgency. At the beginning of life this is generally recognized, but at the other extreme there is a tendency to put off and to hope that the condition will either subside or yield to chemotherapeutic *treatment and operation be avoided. Many lives are lost in this* way and there is much less risk in advising early intervention than in countenancing delay. The difficulties in diagnosis must be acknowledged but many cases even in extreme age are quite unmistakable.

After these observations it may be laid down as a general rule that *every case of acute appendicitis should be operated upon as soon as possible after diagnosis.* In the majority there is no difficulty in arriving at a correct diagnosis, not only that the appendix is at fault but also of the extent of the pathological processes associated with it. On occasion there may be uncertainty, but the properly trained surgeon will never fall into the error of supposing that every patient with pain referred to the right iliac fossa is necessarily suffering from appendicitis. It is not possible within the scope of this work to discuss the problems of differential diagnosis, but it may be reiterated that in the presence of suggestive symptoms the most valuable sign of appendicitis is easily-elicited tenderness over the appendix area.

Indications for removal of the "quiescent" appendix.—There is so marked a tendency for the appendix which has once become inflamed to suffer from recurrent attacks that the question arises whether it should always be removed after the first attack. It is now the general opinion that this is the correct treatment. While it is safe to predict that relapses will occur if the quiescent appendix is not removed, it is impossible to give any opinion as to the probable interval, the severity of future attacks or the menace to life But the risk attached to a relapsing appendicitis does not consist solely in the danger of acute exacerbations. In the intervals between the attacks, and often without any marked attack, a diseased appendix may be lowering the health of its host Many patients never quite lose their pain and suffer from epigastric discomfort, flatulence, constipation and the so-called "appendix dyspepsia". In others, adhesions give rise to

dragging pains and perhaps to delay in the passage of fæcal matter in the ileum.

Both duodenal ulcer and cholecystitis have been considered to result from appendix infection. *B. coli* infections of the urinary tract or chronic or subacute arthritis may be the result of absorption from the appendix and there may be other evidence of infection.

Preparation for operation.—*In acute cases* it may be necessary to adopt measures such as are used in peritonitis to combat the toxic effects of intra-abdominal inflammation (p. 1144). Patients will be more

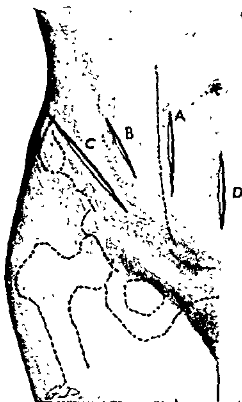


Fig. 468.—Appendicectomy incisions.

(A) Retrorectus (Battle's); (B) gridiron (McBurney's); (C) Rutherford Morison's; (D) median sub-umbilical

comfortable during the immediate post-operative period, and after-treatment will be facilitated, if the lower bowel has been cleared. Purgatives must not be administered and only a small enema can be permitted. Usually there is too much tenderness to permit proper local preparation of the operation area and this should be carried out in the theatre after the patient has been anæsthetized. *In interval cases* the usual preparation for any abdominal operation should be employed.

Anæsthesia.—Unless there is some active chest trouble general anæsthesia can be safely employed. Post-operative chest complications are unusual, not only because of the improvements in the methods

of anæsthesia but because the intervention is limited to the lower quadrant of the abdomen. It is necessary to warn against the use of chloroform in the acute cases, as serious liver changes may occur with fatal results. Spinal anæsthesia is quite satisfactory, and local anæsthesia can be employed, but with the latter method the patient may be subjected to a good deal of pain during the separation or delivery of the appendix and especially in the acute cases

Technique.—Incisions.—The incisions usually employed and strongly advocated are oblique and directly over the appendix such as the

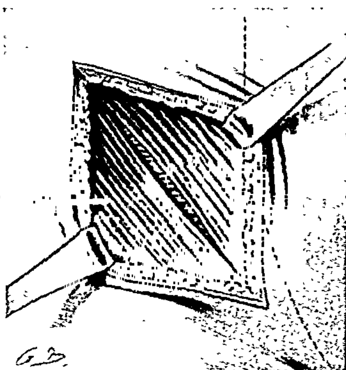


Fig. 469A.—Appendicectomy by McBurney's muscle-separating incision.

1 Aponeurosis of external oblique. The dotted line indicates the outer border of the rectus For clarity, the incision is depicted as longer than is usually employed.

McBurney muscle separation or the muscle-cutting incision of Rutherford Morison. In some few cases where the diagnosis is doubtful one of the vertical incisions may be employed. (Fig. 468.)

McBurney's incision* is made obliquely at the junction of the middle with the outer third of a line joining the umbilicus with the anterior superior spine. (Fig. 468, B) The aponeurosis of the external oblique is exposed, and a way made through it by separating its fibres, which run practically parallel with the incision (Fig. 469A.) The edges of the separated aponeurosis are held apart, and the internal oblique exposed, the muscle fibres crossing the space almost *horizontally*. An opening is made between the fibres of this muscle by a

* *Ann. Surg.*, July, 1894, xx, 35

blunt dissector, exposing the transversalis muscle. (Fig. 469B.) Both muscles are separated at the same time until the peritoneum is reached. The aperture thus made can be stretched by the blunt dissector and the finger until it is about 2–2½ inches long. (Fig. 470.) The musculo-cutaneous branches of the 12th intercostal nerve at the inner end, and the ilio-hypogastric and ilio-inguinal nerves at the outer end of the space, may be seen and should be carefully preserved. The peritoneum is held up in forceps and incised between them, the forceps are left attached to the peritoneal edge and are very useful

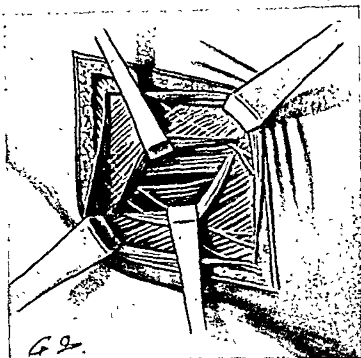


Fig. 469B.—Appendicectomy by McBurney's incision : transversalis muscle exposed by withdrawing external oblique laterally and internal oblique longitudinally. The internal oblique and transversalis are usually drawn apart together.

Note 12th nerve above and ilio-hypogastric and ilio-inguinal nerves below.

when the opening comes to be closed. Full separation of the muscles will give a working space which is enough in most cases. If more room is required the separation of the deep muscles may be carried inwards in the same line and the rectus sheath incised. The rectus muscle can then be retracted inwards and the opening in the peritoneum considerably enlarged.

The peritoneum is closed by a continuous catgut suture. The retractors holding aside the transversalis and internal oblique muscles are withdrawn, allowing the muscles to fall together when they are united by two or more catgut sutures. Great care should be taken that these sutures include the whole thickness of both muscles. The aponeurosis of the external oblique is closed by catgut suture. Finally, the

skin incision is united according to the practice of the operator. The operation is designed to prevent post-operative weakness of the scar by avoiding the cutting of muscles. Its advocates maintain that less pain is complained of afterwards. There is no doubt that recovery is very satisfactory and quick. In the great majority of cases even

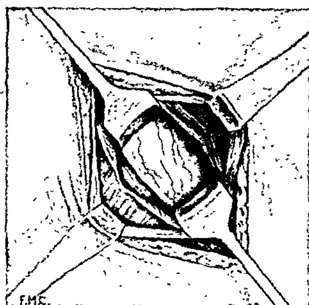


Fig. 470.—McBurney's incision: the peritoneum exposed. As a rule the retractors are not required.

strenuous work can be resumed at the end of a month. The exposure is not so ample as that obtained by the oblique muscle-cutting incisions and in the practice of the writer it is usually reserved for interval cases (group 7). When employed in acute cases and drainage is considered to be necessary a tube or strand of rubber tissue may be brought directly through the wound but a weak spot is very likely to develop and to be followed by hernia. Another plan is to bring the drain through an independent opening to the outer side. Such an opening is often spoken of as a stab wound.



Fig. 471.—Oblique muscle-cutting incision of Rutherford Morison.

The oblique muscle-cutting incision of Rutherford Morison (Fig. 468, c)—First described in *Lancet** this method has since that time been used by the Newcastle school for acute cases almost to the exclusion of any other type of incision. It is made parallel with the outer third of Poupart's ligament

* Feb 23, 1901, i, 533.

and the crest of the ilium. (Fig. 471.) The length of the incision depends on the build of the patient and the conditions expected, and in this matter technique is helped by accurate diagnosis of the probable position of the appendix. If the clinical indications suggest that the appendix is lying in the sulcus on the outer side of the cæcum, then the incision is made with its centre just opposite the anterior superior spine and need not be more than 3 or 3½ inches in length. If, on the other hand, the indications point to a pelvic

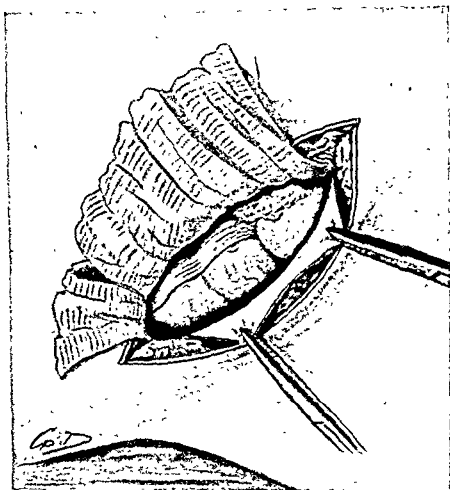


Fig 472.—The oblique muscle-cutting incision: exposure of the sulcus on the outer side of the cæcum and protection of the general peritoneum by gauze.

appendicitis, then it is made further forwards, i.e. from just internal to the anterior superior spine to the outer border of the rectus muscle. In any event the incision can be readily extended either backwards or forwards as the condition demands. It has the supreme advantage that it leads the surgeon directly down to the site of the trouble wherever the appendix is situated, so that it is never necessary to approach a pathological process through the healthy peritoneal cavity. By its aid it is possible to deal with all varieties of appendix abscess without troublesome retraction, for everything necessary can be done

under the guidance of the eye. (Figs. 472 and 473.) As a rule it is best to avoid cutting the deep epigastric artery, as secondary hæmorrhage from this vessel is not unknown and may be a serious complication. Drainage can be most conveniently arranged by

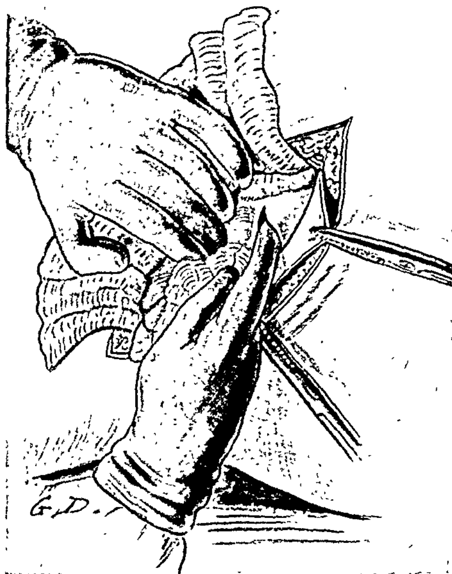


Fig. 473.—Oblique muscle-cutting incision : the surgeon is opening an abscess under the guidance of the eye.

bringing the tube from the posterior end of the incision. The incision must always be closed by careful layer suture, continuous for the peritoneum, interrupted for the other layers. In this way the small intestine area is avoided and the risk of ventral hernia greatly diminished.

The choice of incision.—The McBurney incision is most satisfactory for the interval cases and is now commonly employed for all types of appendicitis Except where a general exploration is necessary, the

oblique muscle-cutting incision of Rutherford Morison fulfils all the indications and is better suited than any of the others for dealing with the retro-cæcal appendix and for abscess.

Removal of the appendix in quiescent cases. (Group 7).—Many surgeons believe that the operation should always be exploratory in interval cases, and for that reason they use one of the rectus incisions from which any part of the abdominal cavity may be examined. The writer prefers to act [illegible] 'e content to examine and remove [illegible] incision. When there is reasonab [illegible] the other incisions is chosen. On opening the peritoneum the cæcum may be seen at once or it may readily be found by introducing a couple of fingers into the wound or using a pair of blunt forceps such as a sponge handle. In the first instance just enough of the bowel should be withdrawn to enable the surgeon to get a secure hold. Quite often the appendix follows the cæcum into the wound. If not, the finger may be introduced by the side of the bowel and in many cases the appendix can then be delivered easily and satisfactorily. When the appendix is not readily found, the surgeon must trace the longitudinal bands towards its base. Sometimes this search means bringing quite a considerable portion of the cæcum outside the wound. When the appendix is found but does not slip easily outside, it may be grasped with forceps and gentle traction used, when, as a rule, it can be brought to the surface. To deal with the base of the appendix properly, this part of the bowel must be brought up to the surface or completely outside. In a few cases, and especially those where there has been a previous abscess, the appendix may be very adherent or may lie behind the cæcum or over the brim of the pelvis or otherwise out of the way. In these circumstances the use of narrow-bladed retractors in the wound may enable it to be seen so that the adhesions can be separated under the guidance of the eye. When there is difficulty in delivering the organ it may be a help to clamp and divide the mesentery in the first instance and that can sometimes be readily done. It is never permissible to pull so forcibly as to risk tearing the appendix across in the depth of the wound or pulling it away from its mesentery. Mobilization of the cæcum by incising the peritoneum on its outer side and gently insinuating the finger may greatly assist in delivery of the appendix. Whenever real difficulty is found the incision must be enlarged as already described. Once the appendix has been withdrawn, the next step is to deal with the mesentery. This may be clamped with one or more artery forceps, divided, and then tied in sections, or it may be transfixed and ligatured before division. Sometimes a vessel very close to the cæcum manages to escape and must be separately caught and tied. By gentle traction the base of the appendix is next thoroughly exposed right up to the bowel, so that the organ appears to be arising at the apex of a cone of cæcum. It is then crushed with a pair of artery forceps through its cæcal

under the guidance of the eye. (Figs. 472 and 473.) As a rule it is best to avoid cutting the deep epigastric artery, as secondary hæmorrhage from this vessel is not unknown and may be a serious complication. Drainage can be most conveniently arranged by

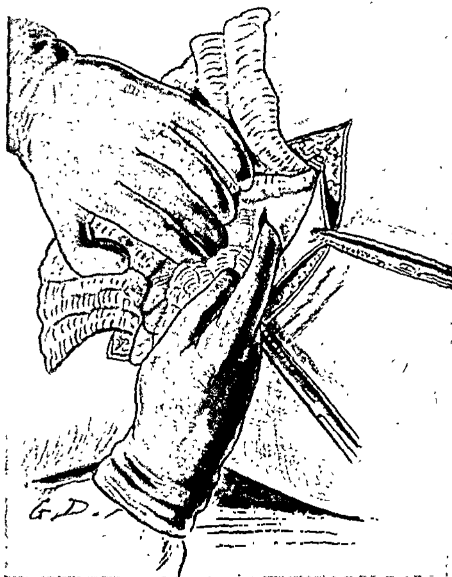


Fig. 473.—Oblique muscle-cutting incision : the surgeon is opening an abscess under the guidance of the eye.

bringing the tube from the posterior end of the incision. The incision must always be closed by careful layer suture, continuous for the peritoneum, interrupted for the other layers In this way the small intestine area is avoided and the risk of ventral hernia greatly diminished

The choice of incision.—The McBurney incision is most satisfactory for the interval cases and is now commonly employed for all types of appendicitis Except where a *general exploration* is necessary, the

oblique muscle-cutting incision of Rutherford Morison fulfils all the indications and is better suited than any of the others for dealing with the retro-cæcal appendix and for abscess.

Removal of the appendix in quiescent cases. (Group 7).—Many surgeons believe that the operation should always be exploratory in interval cases, and for that reason they use one of the rectus incisions from which any part of the abdominal cavity may be examined. The writer prefers to act on a pre-operative diagnosis and to be content to examine and remove the appendix through a McBurney incision. When there is reasonable doubt in the diagnosis one of the other incisions is chosen. On opening the peritoneum the cæcum may be seen at once or it may readily be found by introducing a couple of fingers into the wound or using a pair of blunt forceps such as a sponge handle. In the first instance just enough of the bowel should be withdrawn to enable the surgeon to get a secure hold. Quite often the appendix follows the cæcum into the wound. If not, the finger may be introduced by the side of the bowel and in many cases the appendix can then be delivered easily and satisfactorily. When the appendix is not readily found, the surgeon must trace the longitudinal bands towards its base. Sometimes this search means bringing quite a considerable portion of the cæcum outside the wound. When the appendix is found but does not slip easily outside, it may be grasped with forceps and gentle traction used, when, as a rule, it can be brought to the surface. To deal with the base of the appendix properly, this part of the bowel must be brought up to the surface or completely outside. In a few cases, and especially those where there has been a previous abscess, the appendix may be very adherent or may lie behind the cæcum or over the brim of the pelvis or otherwise out of the way. In these circumstances the use of narrow-bladed retractors in the wound may enable it to be seen so that the adhesions can be separated under the guidance of the eye. When there is difficulty in delivering the organ it may be a help to clamp and divide the mesentery in the first instance and that can sometimes be readily done. It is never permissible to pull so forcibly as to risk tearing the appendix across in the depth of the wound or pulling it away from its mesentery. Mobilization of the cæcum by incising the peritoneum on its outer side and gently insinuating the finger may greatly assist in delivery of the appendix. Whenever real difficulty is found the incision must be enlarged as already described. Once the appendix has been withdrawn, the next step is to deal with the mesentery. This may be clamped with one or more artery forceps, divided, and then tied in sections, or it may be transfixed and ligatured before division. Sometimes a vessel very close to the cæcum manages to escape and must be separately caught and tied. By gentle traction the base of the appendix is next thoroughly exposed right up to the bowel, so that the organ appears to be arising at the apex of a cone of cæcum. It is then crushed with a pair of artery forceps through its cæcal

under the guidance of the eye. (Figs. 472 and 473.) As a rule it is best to avoid cutting the deep epigastric artery, as secondary hæmorrhage from this vessel is not unknown and may be a serious complication. Drainage can be most conveniently arranged by

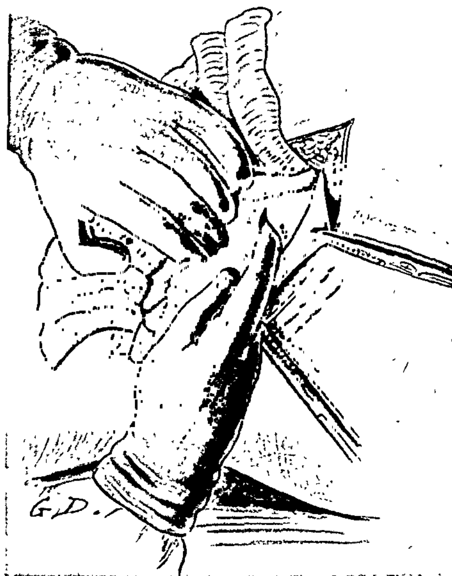


Fig. 473.—Oblique muscle-cutting incision : the surgeon is opening an abscess under the guidance of the eye.

ringing the tube from the posterior end of the incision. The *incision* ıust always be closed by careful layer suture, continuous for the eritoneum, interrupted for the other layers. In this way the small itestine area is avoided and the risk of ventral hernia greatly minished

The choice of incision.—The McBurney incision is most satisfactory r the interval cases and is now commonly employed for all types of ppendicitis Except where a general exploration is necessary, the

not infrequently to result from burying the stump by the purse-string method. It is stated that an abscess may form at the site and may burst into the bowel, or give rise to peritonitis or to abscess in the liver. In other cases, chronic inflammatory trouble may follow, with persistent pain, tenderness and other signs of peritoneal irritation. As a late result, a diverticulum is said to occur at the site, carrying the risks associated with diverticula in general. It is therefore suggested that it is safer and better merely to ligate the appendix and either divide it with the cautery or carbolize the stump which is left unburied. This technique is used both in quiescent and acute conditions. It is well known that in the great majority of cases this plan is sufficient, but burying the stump ought to provide additional security and does seem to have stood the test of time in the hands of British surgeons. Other plans have been suggested, and it is necessary to warn against simply tucking in the stump without ligature, as deaths from hæmorrhage into the bowel have followed this method. Hæmorrhage into the bowel has also occurred when the stump has been ligated with catgut and for this reason some surgeons following the practice of the late Sir David Wilkie always use silk for this ligature.

Operation in acute appendicitis.—The choice of approach is largely influenced by the teaching of the different surgical schools. The vertical rectus incisions have for long been popular but have the disadvantage that if the inflamed appendix is situated anywhere on the outer side of the cæcum it must be approached through peritoneum, which is probably uninvolved in the inflammatory process. Further, should it be necessary to leave in a drain, it has to pass through the abdominal wall at a site where hernia is likely, or an independent incision must be made for the purpose. The incisions directly over the appendix region have the great advantage that the site of the disease is immediately exposed when the peritoneum is opened. The muscle-separating incision of McBurney, which is so satisfactory for the quiescent cases, is now also commonly used for the acute cases. However, it must be recognized that it may be more difficult to deliver the gangrenous or inflamed appendix through the limited space available without the risk of its being torn or ruptured and, if it happens to be situated in the pelvis or behind the cæcum or far up on its outer side, much harmful manipulation may be needed. The results reported, however, are very satisfactory but probably owe a good deal to the earlier operation which is now usual and to the protection afforded by chemotherapy. The oblique muscle-cutting incision of Rutherford Morison gives the best exposure and has the advantage that it can be extended forwards towards the pelvis or backwards towards the loin as the occasion demands. Used in this way it will meet the indications in any circumstances likely to be encountered. The experience of many years in large numbers of cases long ago convinced the writer of the superiority of this incision, but a far better testimony to its value is the fact that a

attachment. (Fig. 474). The forceps is removed and a ligature applied to the crushed area and firmly tied. The forceps is then re-applied to the appendix about ½ inch beyond the ligature and the organ is cut across on the cæcal side of the forceps. The ligatured stump should be wiped dry with a pledget of gauze and then may be swabbed with pure carbolic. If there is a considerable portion of mucous membrane on the stump it should be trimmed down with scissors. Finally the stump is buried with a purse-string suture of chromicized catgut. A second suture, not necessarily a purse-string, should be introduced over the first. This adds additional security and leaves a perfectly smooth peritoneal surface at the site of the appendix stump.

The cæcum is then returned to the abdomen and the wound closed in layers. In this operation it is not necessary to pack off the peritoneal cavity. The exposed bowel should be covered while the stump is dealt with and a gauze swab may be used to prevent the further escape of bowel, but with the McBurney incision there is little tendency to this. The incision has the disadvantage that if the appendix is not easily found and a considerable portion of bowel has to be drawn up through what may be a rather tight aperture in the abdominal wall, it soon becomes distended and congested and it may be difficult to return it to the abdomen without tearing its peritoneal coat or producing a subperitoneal hæmatoma. To avoid this trouble the bowel should be replaced in the abdomen as soon as the appendix is found, only so much being left outside as will enable the surgeon to deal safely with the base of the appendix. Extruded bowel that has to be returned after it has become distended and congested should be covered with a large gauze and its contents gently squeezed into the colon in the abdomen. After considerable pressure the surgeon will feel the contents gurgling back into the intestine and, as a result, the bowel will become quite flaccid and can be readily returned through the small incision. The operator must avoid the temptation to use any sharp-pointed instrument in thrusting the cæcum back. Any peritoneal tears that may have occurred should be drawn together with a few points of suture. If a considerable area is involved it may be covered and tucked in by using a continuous suture. Whatever difficulties may be encountered in removing the quiescent appendix, it should always be remembered that they will all disappear with proper exposure. In spite of what is often said to the contrary it is not good practice to convert the McBurney incision into a muscle-cutting one. The trauma involved is considerable and in spite of careful suturing a weak area in the abdominal wall often results. The writer would strongly urge the beginner to employ the oblique muscle-cutting incision for his earlier cases and for those in which there has been a previous history of abscess.

Alternative methods of dealing with the appendix stump.—American surgeons* have drawn attention to various after-troubles that are said

* Alton Ochsner and Lilly, *Surgery* 1937, No 4, ii, 532.

many years. The writer has always made it a practice to bury the ... lt with the least risk ... In operating in the acute phase it is not always possible to do this satisfactorily because the parts about the base may be so much thickened and indurated. In these circumstances, after ligation, the stump may be seared with the cautery, or carbolized, and left exposed, but a tube or rubber tissue drain should always be brought from the neighbourhood. Gauze should not be employed as a drain, or protective lymph tissue may be torn away when it is removed. In most acute cases, especially groups (1) and (2), the stump can be buried and the abdomen closed without provision for drainage.

Management of the mesentery.—When the mesentery is not overloaded with fat it can very conveniently be caught in one or more pairs of artery forceps and divided, the tissue in each pair of forceps

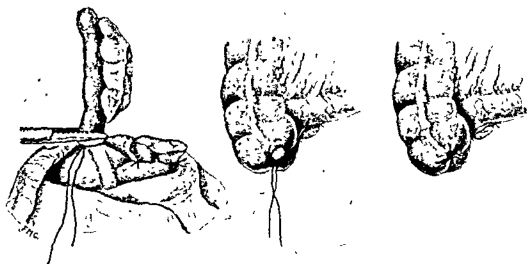


Fig. 474.—Appendicectomy by simple clamp and purse-string method.

being separately ligatured. It is seldom necessary to use more than three pairs of forceps and quite often a single bite will suffice. When the mesentery is very fat it must be divided well beyond the forceps, as there is risk of the vessels retracting and causing what may prove to be a very troublesome hæmatoma in the mesentery and beyond. The inflamed mesentery may be so friable that the ligature cuts itself loose. In these circumstances the vessels must be caught again and a ligature on a needle passed back and forth through the mesentery; well above the bleeding site, and tied. When the vessels can be readily seen the mesentery may be transfixed and secured by ligation, but when they are not seen there is a risk of puncturing them and some trouble may result. It is always possible to secure the vessels in the mesentery, but there are occasions when there may be a little bleeding from the area to which the appendix has been adherent. As a rule this is an ooze which will cease on pressure. Occasionally a

succession of assistants have adopted it and continue to use it with complete satisfaction. In females, where there may be doubt about the diagnosis between tubal inflammation and appendicitis, or in doubtful cases in the male, the midline subumbilical incision should be used.

The length of the Morison incision will be governed by the type of case and the anatomical build of the patient. For all but abscess cases and in those of average build, an incision about 4 inches long will give a sufficient exposure. In the abscess group (6) and especially in stout people, an incision of from 5 to 6 inches, or even longer, may be required, but it can be so readily enlarged either forwards or backwards that it is not necessary to make it very long in the first instance. In making this incision it is important not to carry it as far forward as the deep epigastric artery in the first instance Should an inward extension be necessary, it may be carried right up to or even into the rectus sheath, *but in that case the deep epigastric vessels should be deliberately caught, ligatured and divided so that the secured ends can retract out of* harm's way. As soon as the peritoneum is opened there may be an escape of exudate some of which will probably flood the wound. As much as possible should be mopped up with gauze, or the suction apparatus may be used. The appendix may immediately come into view or it may be felt as soon as the finger is introduced. When it is not easily found the operator should trace the longitudinal bands on the cæcum which lead to its base and with this as a guide the organ will nearly always be readily found, and can be freed by the finger passed along towards its tip. Should the appendix be tucked away under the cæcum or colon, it is very helpful to cut through the peritoneal bands and attachments which so often tie the bowel down to the iliac fossa After this has been done the cæcum may be displaced inwards, disclosing the hidden appendix, which may pass up behind the colon, sometimes in the retro-peritoneal tissues. Sometimes the meso-appendix is too short to allow the organ to be brought up into the wound. In these circumstances it will be necessary to clamp and divide the mesentery. Even after this step, there are some few cases in which the appendix cannot be readily extruded, especially in abscess cases. In these circumstances it should be clamped across at its base and divided, after which it can usually be separated and delivered by working in a retrograde fashion. Of course, the proximal end must be ligatured and tucked into the cæcum either before enucleation or after. (Fig. 474) Occasionally even this method of removal is difficult or well-nigh impossible, and in this small residue the mucous membrane may be enucleated from the thickened and indurated outer coats. To accomplish this, the outer coats are incised down to the submucous layer and this " inner appendix " is caught in forceps; traction aided by forceps dissection will usually complete its enucleation. The thickened outer coats are left undisturbed.

Management of the stump of the appendix.—The treatment of the *appendix stump has led to a considerable* amount of discussion over

postponed to a later intervention during the quiescent period. It is in these abscess cases that the perforated appendix is most likely to be encountered, and it is necessary to take great care that the whole organ is removed. Not infrequently the appendix is separated into two portions at the site of a perforation. It should be very carefully examined immediately after removal so that, if there is any doubt about its completeness, search can be made for the remaining part.

Perforations near the base of the appendix are often associated with severe general peritonitis (group 4 cases) or with large abscesses. Such a perforation may extend into the cæcum and may not be occluded by the encircling ligature of the base of the appendix. Great care must be taken to close such holes by suture, and it is wiser to provide drainage. In abscess cases an enterolith is sometimes loose in the pus or may be hidden in the recesses of the cavity, and it is well to explore with the finger to make quite certain that no such foreign body remains behind. When the omentum is closely wrapped about the appendix or is thickened and involved in the inflammatory process, it can often be separated with ease, and should be preserved and used for packing down into the area after the removal of the appendix. When, on the other hand the adhesions are so firm that it can only be separated from the appendix with difficulty, it may be ligatured off and removed with the organ. In these circumstances it is important to divide the omentum through the area which is presumably healthy, otherwise there is a risk of displacing septic thrombi which might perchance cause portal pyæmia.

In *the retro-cæcal cases* the inflammatory process sometimes spreads to the iliacus or the psoas muscles. This may be an extension from an abscess about the appendix or its tip may be directly adherent to the sheath of the muscles and the whole abscess may be situated among the muscular fibres. In either case the thickened muscle sheath must be freely incised so that the abscess can be emptied and drained. This complication of appendicitis may be diagnosed with confidence when psoas rigidity is present as a symptom. When using the oblique incision any necessary drain is brought out at its posterior end, at which there is much less liability to hernia. (Fig. 471.) The omentum, when accessible, should be pulled down to the appendix site and laid in the sulcus on the outer side of the bowel. The wound must always be carefully closed in layers with catgut, the peritoneum with a continuous suture, and the muscles in at least two layers by interrupted sutures. Chromicized gut should be employed; size 3/0 is suitable for the peritoneum and No. 0 for the muscles, or, in muscular men, size No. 1. There is said to be a lesser incidence of wound infection if nylon is the suture material employed. It is not wise to overlap the external oblique in the acute cases as this might encourage cellulitis of the abdominal wall. The skin is closed with interrupted sutures of silkworm gut or similar material ¾ inch apart. The whole idea is to provide ready exit to the surface for discharge should sepsis occur in the wound. Where there is gross infection there may be a

vessel may require ligation or the administration of one of the fibrin coagulants. Sometimes the oozing can only be controlled by packing gauze rather firmly over the site. Such gauze must be left *in situ* and brought out of the wound with the drainage tube. When a gangrenous process extends into the meso-appendix there is a special risk of portal pyæmia and great care should be taken to secure the mesentery well above the affected area.

Drainage.—Drainage requires consideration and does not only concern the security of the ligatured stump. The present-day practice is to dispense with provision for drainage except where the security of the closure of the stump of the appendix is in doubt or where there is a thick-walled abscess of considerable size. Where there is thick pus or much infected tissue that will probably necrose or a considerable oozing area it may be a safeguard to provide a drain. In any event there may be nothing to drain at the termination of the operation and it is merely a question of providing a ready track to the surface in case of subsequent exudation or continuing suppuration or to prevent hæmatoma. Such a track may be ensured by the insertion of a small softened tube or a strand of rubber tissue. The track will be established in four or five days when the tube may be removed either at once or by stages.

In *the abscess case* the oblique incision proves an enormous advantage because it means that the surgeon will come down directly to the seat of the mischief. On occasion, as soon as the peritoneum is opened pus will be found, but in other cases the peritoneal cavity is free, the abscess being shut off entirely within the abdomen. In these circumstances the general peritoneum is protected by gauze over the cæcum, towards the pelvis and towards the right loin. If the abscess is not situated in the sulcus on the outer side of the cæcum it will be found towards the pelvis, or the loin pouch, or behind the cæcum, and in all probability the guide to its location will be adhering omentum or the distal end of the appendix passing into the inflammatory mass. The peritoneum having been protected, the abscess must be opened. Its wall can usually be broken down by the finger and only on rare occasions will it be necessary to use scissors. With the oblique incision the pus runs readily to the surface over the posterior part of the wound and can usually be controlled by gauze swabbing, though no amount of care is likely to prevent some soiling, but the wound usually heals perfectly well in spite of contamination. When the abscess has been emptied and dried the appendix may be obvious or may at least be readily found after a limited search. Though it is highly desirable to be rid of the appendix, and though this can safely be done in a considerable proportion of abscess cases, it is not essential for immediate recovery. To set out to remove the appendix at all costs causes an unjustifiable increase in the mortality. In cases of difficulty it is therefore best not to run the risk of inflicting unnecessary trauma, or spreading infection, in attempts at removal which should be

postponed to a later intervention during the quiescent period. It is in these abscess cases that the perforated appendix is most likely to be encountered, and it is necessary to take great care that the whole organ is removed. Not infrequently the appendix is separated into two portions at the site of a perforation. It should be very carefully examined immediately after removal so that, if there is any doubt about its completeness, search can be made for the remaining part.

Perforations near the base of the appendix are often associated with severe general peritonitis (group 4 cases) or with large abscesses. Such a perforation may extend into the cæcum and may not be occluded by the encircling ligature of the base of the appendix. Great care must be taken to close such holes by suture, and it is wiser to provide drainage. In abscess cases an enterolith is sometimes loose in the pus or may be hidden in the recesses of the cavity, and it is well to explore with the finger to make quite certain that no such foreign body remains behind. When the omentum is closely wrapped about the appendix or is thickened and involved in the inflammatory process, it can often be separated with ease, and should be preserved and used for packing down into the area after the removal of the appendix. When, on the other hand the adhesions are so firm that it can only be separated from the appendix with difficulty, it may be ligatured off and removed with the organ. In these circumstances it is important to divide the omentum through the area which is presumably healthy, otherwise there is a risk of displacing septic thrombi which might perchance cause portal pyæmia.

In *the retro-cæcal cases* the inflammatory process sometimes spreads to the iliacus or the psoas muscles. This may be an extension from an abscess about the appendix or its tip may be directly adherent to the sheath of the muscles and the whole abscess may be situated among the muscular fibres. In either case the thickened muscle sheath must be freely incised so that the abscess can be emptied and drained. This complication of appendicitis may be diagnosed with confidence when psoas rigidity is present as a symptom. When using the oblique incision any necessary drain is brought out at its posterior end, at which there is much less liability to hernia. (Fig. 471.) The omentum, when accessible, should be pulled down to the appendix site and laid in the sulcus on the outer side of the bowel. The wound must always be carefully closed in layers with catgut, the peritoneum with a continuous suture, and the muscles in at least two layers by interrupted sutures Chromicized gut should be employed; size 3/0 is suitable for the peritoneum and No. 0 for the muscles, or, in muscular men, size No 1. There is said to be a lesser incidence of wound infection if nylon is the suture material employed. It is not wise to overlap the external oblique in the acute cases as this might encourage cellulitis of the abdominal wall. The skin is closed with interrupted sutures of silkworm gut or similar material ¾ inch apart. The whole idea is to provide ready exit to the surface for discharge should sepsis occur in the wound. Where there is gross infection there may be a

little localized cellulitis, or an abscess may form in the wound, part of which has then to heal by granulation. Efforts have been made to prevent infection of the parietes by the local use of sulphonamides, but the writer is not yet convinced that these have proved of great value against *B. coli*, which is the usual organism. [illegible] infection, which is quite unusual, wound [illegible] and the proportion of weak scars or of d[illegible] and certainly no greater than after any of the other incisions. When *acute appendicitis is approached through one of the vertical incisions* it is necessary to work along the ileum to the cæcum. When the latter is freely movable it may be easy to expose it and to draw it forward, but should it be tied down then the operation may be very difficult. When there is a collection of infected fluid or a localized abscess about the appendix there is a very considerable risk that the peritoneum will be fouled. Free use must be made of gauze swabbing and of the aspirator. When necessary a small drain may be brought out through the lower part of the vertical incision, but this can only be done with the knowledge that it does increase the risk of incisional hernia.

Prophylaxis of infection.—The present tendency is to use a sprinkling of one of the sulphonamide antiseptic powders over an infected or inflamed area but considerable quantities or " lumping " should not be inserted When there is spreading inflammation or signs of marked absorption chemotherapy and antibiotics should be used systemically.

Accidents that may happen during operation for acute appendicitis.—The bowel may be torn during the separation of the cæcum or lower end of the ileum. As a rule, such a tear would only involve the outer coats, but if the viscera are much softened by inflammation the lumen may be inadvertently opened. There is also the possibility that an abscess may have burst into the bowel and that the opening thus made may be exposed. But whatever the cause, the defect must be closed in the ordinary way with two layers of suture. If *on account of the softened condition of the bowel, the suturing is* inefficient, there is additional reason for drainage, and in these circumstances it is wiser to place a piece of rubber sheeting over the sutured area, and to use a rather larger tube than would *ordinarily suffice.* Gauze should not be used for this purpose. When only the outer coats of the bowel are torn, the mucous membrane may bulge into the rent, this should be remedied by drawing the tear together with a few catgut sutures On rare occasions, when the lower end of the ileum has been much involved in the inflammatory thickening and œdema, it has been mistaken for the appendix and a considerable section of its inner coat has been enucleated under the assumption that the appendix was being isolated for removal If the accident is discovered after only an inch or two of the inner bowel has been separated, it may be allowed to retract into position and the outer coat repaired by a few stitches. Probably no harm will follow, but provision must be made

for drainage lest necrosis and leakage occur. If anything more than this small amount has been separated—the writer once inadvertently enucleated a piece of bowel 11 inches in length in this way—then the only rational way to deal with the accident is to resect the damaged bowel, tuck in the cæcal end if very short and make an anastomosis between the ileum and the cæcum or ascending colon.

Complications after operation for acute appendicitis.—In the first few days there may be diffuse peritonitis, ileus, cellulitis and sloughing of the abdominal wall and chest complications. Later, fæcal fistula, pelvic abscess, subphrenic abscess, obstruction from intestinal adhesions, pylephlebitis, and, last of all, persistent sinus and scar hernia may occur, though fortunately very infrequently.

Some few patients complain of indifferent health, which is usually attributed to adhesions persisting after convalescence. In such cases it is much more likely that the original diagnosis has been at fault and that some other condition, such as duodenal ulcer, a chronically inflamed gall-bladder, or hydronephrosis is the cause.

Diffuse peritonitis is generally a continuation of the septic process originating in the appendix. Cases of a certain type show a steady downward tendency, apparently uninfluenced by the removal of the appendix and appropriate after-treatment. It is very important to differentiate between ileus and diffuse peritonitis, as the treatment of these two conditions is somewhat different. The subject is discussed at p. 1149. It is sufficient to say here that if diffuse peritonitis, not existing as such before the operation, follows an operation for acute appendicitis, active treatment must be instituted on the lines [illegible] (p 1144); but the prognosis must be considered grave.

and the antibiotics will probably reduce the incidence considerably and will modify and quickly terminate those which do occur.

Fæcal fistula is only likely in cases complicated by abscess. If the appendix has not been removed a perforation near its base may be the cause. Such cases are readily dealt with by removal of the appendix. In other circumstances the condition results from the discharge of an abscess into the bowel, or is the result of necrosis following infection or injury during the operation. In the *cæcum* the fistula generally arises as the result of direct extension of the appendicular infection to its wall; in the *small intestine* it more usually follows a second operation for pelvic abscess or intestinal obstruction due to adhesions. It is an interesting fact that a fæcal fistula from the cæcum is not a very serious complication and indeed, in many cases it is followed by a rapid improvement in the patient's condition. Such a fistula also tends to close spontaneously, but this is not likely if it persists for more than three or four weeks.

To close a cæcal fæcal fistula.—If minor methods, such as cauterizing the edges of the opening, are unavailing, operation will be required. The greatest difficulty may be experienced in cleaning the skin, but fortunately local immunity and the use of chemotherapy comes to the surgeon's aid and incisions made in fæcal soiled tissues usually heal kindly. The bowel is cleared out by irrigation both from the fistula and from the anus but, as fluid fæces are constantly passing into the cæcum from the ileum, the fistula must be controlled before the operation begins. This may be done by packing gauze into the opening, or by over-sewing it after the skin incision surrounding the fistula has been made. An adequate elliptical incision is employed, enclosing the fistula at its centre. The incision is deepened to expose the peritoneum in its whole length and the latter is opened at the upper end of the incision as far as possible from the fistula, because at this point the bowel is least likely to be adherent. A finger is introduced, and the extent of the attachment of the cæcum to the anterior abdominal wall ascertained. The peritoneum is then carefully divided throughout the length of the incision and on both sides of the ellipse, thus isolating the fistula. The cæcum, still with its fistula attached, is withdrawn from the wound, and the general peritoneal cavity shut off with swabs. If the cæcum can be lifted out sufficiently, it may be lightly clamped to prevent extravasation of its contents but this is rarely necessary, and may perhaps damage its wall, which is very thin and less able to resist even slight trauma owing to previous inflammation. The fistula is then cut away, and the resulting opening closed by a double layer of catgut sutures, the first passing through all the coats, the second burying the first Lembert-fashion The cæcum is returned to the abdomen and the parietal incision closed in three layers without drainage.

To close a small-intestine fistula.—The injured intestine may be adherent to the parietes or it may be in the pelvis, the fistulous track

Inguinal hernia following operation for appendicitis.—Occasionally *a right inguinal hernia* has appeared so soon after an operation for appendicitis as to suggest cause and effect. Such a hernia has been particularly noticed after the muscle-separating incision of McBurney and the oblique muscle-cutting incision of Rutherford Morison. It has been stated that the nerves which govern the nutrition of the abdominal wall in the inguinal region are apt to be injured by either of these incisions. On the other hand, this hernia has occurred even when the greatest care has been taken to avoid damage to the nerves. It may be that the presence of a very firm scar in the right iliac fossa throws an especial stress on the inguinal region, so that hernia is more likely, especially if there has been some predisposition. Certainly this hernia may occur when the appendix scar is perfectly strong, and is not usually noticed in cases in which the scar tissue is weak or is the site of an incisional hernia. In irreducible cases the contents of the sac may be found diffusely adherent to its walls, but they can always be separated with time and care. If the muscles look pale and atrophic, fascial sutures should be employed.

Results in acute appendicitis.—As in all operations for acute abdominal conditions, the immediate result depends largely on the interval elapsing between onset and intervention. It is true that there are a few fulminating cases where operation at any stage seems to be particularly unsuccessful, but these are quite exceptional. For statistics to be of any value, cases should be grouped under such headings as "Acute Appendicitis without Suppuration," "Acute Appendicitis with Diffuse Peritonitis," "Acute Appendicitis with Localized Abscess." Some surgeons hold that all should be classified according to the time interval elapsing before operation.

The following figures from the writer's practice, in the days when a fair share of emergency surgery was dealt with, supply a basis for comparison which has proved practical and useful.

Group	—	Cases	Deaths	Percentage
	Acute appendicitis :			
1	without peritonitis	159	0	0 0
2	with localized peritonitis	428	4	0·93
3	with flank or pelvic peritonitis, or both	230	22	9·56
4	with diffuse peritonitis	96	28	29·16
5	with residual abscess	64	5	7·81
6	with primary localized abscess ..	446	16	3·59
7	interval removal	1080	4	0·37
8	with primary complications ..	20	9	45 0
	Total ..	2523	88	3·49

The cases in group 4 covered a period when many examples of late

Inguinal hernia following operation for appendicitis.—Occasionally a right inguinal hernia has appeared so soon after an operation for appendicitis as to suggest cause and effect. Such a hernia has been particularly noticed after the muscle-separating incision of McBurney and the oblique muscle-cutting incision of Rutherford Morison. It has been stated that the nerves which govern the nutrition of the abdominal wall in the inguinal region are apt to be injured by either of these incisions. On the other hand, this hernia has occurred even when the greatest care has been taken to avoid damage to the nerves. It may be that the presence of a very firm scar in the right iliac fossa throws an especial stress on the inguinal region, so that hernia is more likely, especially if there has been some predisposition. Certainly this hernia may occur when the appendix scar is perfectly strong, and is not usually noticed in cases in which the scar tissue is weak or is the site of an incisional hernia. In irreducible cases the contents of the sac may be found diffusely adherent to its walls, but they can always be separated with time and care. If the muscles look pale and atrophic, fascial sutures should be employed.

Results in acute appendicitis.—As in all operations for acute abdominal conditions, the immediate result depends largely on the interval elapsing between onset and intervention. It is true that there are a few fulminating cases where operation at any stage seems to be particularly unsuccessful, but these are quite exceptional. For statistics to be of any value, cases should be grouped under such headings as "Acute Appendicitis without Suppuration," "Acute Appendicitis with Diffuse Peritonitis," "Acute Appendicitis with Localized Abscess." Some surgeons hold that all should be classified according to the time interval elapsing before operation.

The following figures from the writer's practice, in the days when a fair share of emergency surgery was dealt with, supply a basis for comparison which has proved practical and useful.

Group	—	Cases	Deaths	Percentage
	Acute appendicitis :			
1	without peritonitis	159	0	0·0
2	with localized peritonitis	428	4	0·93
3	with flank or pelvic peritonitis, or both	230	22	9·56
4	with diffuse peritonitis	96	28	29·16
5	with residual abscess .. .	64	5	7·81
6	with primary localized abscess ..	446	16	3·59
7	interval removal	1080	4	0·37
8	with primary complications ..	20	9	45·0
	Total ..	2523	88	3·49

The cases in group 4 covered a period when many examples of late

pulmonary œdema. The intravenous route must be used to supply nourishment in the form in which the tissues can most easily use it.

To decompress the hollow viscera a stomach tube is of the greatest help. This may be of the Ryle or the Wangensteen type, which are easily swallowed. If this measure does not bring sufficient relief, or if uncomfortable distension persists, the Miller-Abbot tube may be substituted. It is not always easy for the patient to swallow this tube, and it is necessary to determine radiographically that it has passed into the duodenum. If it is uncomfortable and causes distress it will do more harm than good, and should be abandoned. A distended colon, suggested by bulging in the epigastrium and flanks, may be emptied by the rectal tube which enables flatus that reaches the rectum to escape easily. The output of urine must be watched; in the presence of an ample intake too small an output is a bad prognostic sign, just as free diuresis is of joyful augury. Pain is not usually very severe but may be persistent and distressing. A very small dose ($\frac{1}{16}$ grain) of morphine intravenously sometimes has a wonderful effect. It can be conveniently administered with a hypodermic into the rubber tube used for the drip. This small dose may be repeated every 6 hours until the patient is completely relieved. The indication for morphine is pain, and it is often not so successful for mere weariness or mental distress. For their relief, chloral and bromide, 30 grains of each dissolved in water and given per rectum in 4 ounces of milk or 20 or 30 grains of aspirin by the same route often work wonders.

To combat circulating toxins is the root of the matter and the resources of chemotherapy and the antibiotics must be exploited to the full. If the bowels move it is a good omen but really of secondary importance and purgatives are to be avoided.

When to operate.—If improvement follows these measures the surgeon must watch for the favourable moment to intervene surgically. That may come in 6 or 12 hours or more but if, at any period after 6 hours, improvement seems to have come to a standstill, any surgical intervention felt to be necessary must be carried out. In such cases only the minimum interference is permissible and will probably consist in merely opening a localized abscess or introducing a tube into an unlimited collection in the peritoneal cavity.

After such an intervention the surgeon must not make the mistake of hastily discontinuing the measures directed to combat the peritonitis.

In some cases recovery from the peritonitis is so complete that it need not be interrupted for any sort of surgical intervention, though there is always a stage when the whole problem must be reviewed so that steps may be taken to prevent the recurrence of a condition which has brought the patient so low in health.

Operative technique.—The surgeon must realize that ground may be easily lost, and for that reason any proposed surgical intervention should be conducted with special care. There must be no disturbing preparation and anything that is required in the way of cleansing the

adhesions, the low-grade more than the high-grade infections, so that the common expressions *localized* and *diffuse* only refer to stages in the progress of the disease.

All surgeons agree that when peritonitis is the result of perforation, operation is imperative. When some other definite septic focus is the cause operation is of the greatest value and the only question is the stage at which it should be carried out. On general grounds it should be at the earliest possible moment, but opinions differ on the advisability of operating when there is profound toxæmia and great distension. Thus, many surgeons operate at any stage after the diagnosis has been made, whereas others maintain that in many cases where 48 hours have already elapsed since the onset, operation should be deferred in the hope that the infection will become localized. It is a matter for individual judgment in the particular case. If a rule must be laid down, it would be fair to say that if, at the end of 48 hours, there is no evidence of localization, operation should be undertaken; but if localization is beginning or progressing, expectant treatment should be continued. Of course, most surgeons agree that a localized abscess requires drainage as soon as it is recognized.

Acute Diffuse Peritonitis

Preliminary treatment.—These cases usually arise in association with appendicitis or the perforation of some hollow viscus. As soon as the diagnosis is settled and while preparations are being made for operation or for removal to hospital, the patient should be placed in Fowler's position, unless in a state of grave shock. Nothing whatever should be given by the mouth If a journey has to be undertaken, a dose of morphine and atropine hypodermically should be administered. With marked shock intravenous glucose-saline solution should be employed.

Pre-operative treatment.—In late cases, as judged not only by the lapse of time but by the degree of pathological mischief reflected in the clinical condition, the decision when to interfere depends on the response to treatment. Patients who look ill, have a dry tongue, a quick pulse, chilly extremities, abdominal distension and vomiting are in a desperate state and require prompt treatment. Rest in bed, warmth, the absence of over-fussy attention and an atmosphere of confidence, are all good to begin with, but the indications are to make up for the loss of body fluids and chlorides, to provide nourishment, to decompress the hollow viscera, to promote excretion, to employ the appropriate chemotherapeutic agents or antibiotics and to relieve pain. It is usually recommended that these patients should be nursed in the Fowler position, but at this desperate stage they should be allowed to lie in the position of least discomfort.

Because of the vomiting and distension, fluids cannot be given by mouth, and it is usually best to begin with intravenous administration of glucose-saline solution and plasma A careful watch must be kept on the urinary output and for signs of respiratory embarrassment from

convenient when there is no actual collection to be drained away and it is merely a question of providing a track to the surface. There is much to support the view that the presence of a tube being a foreign body in the peritoneal cavity tends to set the flow of exudate in its direction.

Fowler's position and the administration of saline with glucose and chloride *intravenously* or *per rectum* have been widely adopted. The question of drainage has been discussed above, many of the discomforts are prevented or alleviated by decompression of the stomach with the Ryle tube. In other details the after-treatment is conducted on the lines indicated for pre-operative treatment (p. 1144). What is said about meteorism (p. 1149) may also be applicable.

Complications.—Subphrenic abscess of the intraperitoneal type, as a complication of diffuse peritonitis, is seen most commonly after gastric and duodenal perforations, though it occurs occasionally after acute appendicitis. Extraperitoneal subphrenic abscess does not follow diffuse peritonitis, but may be seen after a retrocæcal appendiceal abscess.

There is no doubt that the incidence of subphrenic abscess has been much reduced by the abandonment of irrigation of the general peritoneum, the adoption of Fowler's position and the employment of chemotherapy in the after-treatment. The chief danger lies in the difficulty of diagnosis leading to delay in treatment.

Diagnosis depends on recognizing the importance of early slight chest symptoms and signs. Examination by the fluorescent screen is most valuable. Whenever the condition is suspected, repeated examination and careful watchfulness are essential. The exploring needle is often the final arbiter, but it must be of sufficient length and bore and used with great circumspection. When the surgeon has good reason to suspect such an abscess, the exploration is better done on the operating table so that the needle may be left *in situ* as a guide and the operation for evacuation of pus, whether by aspiration or incision, proceeded with there and then.

Treatment.—There are three routes for *drainage*—(1) from above, transpleural through the diaphragm; (2) from below, by incision in the hypochondrium, and (3) from behind, after excision of the 12th rib. The avenue to be employed is dictated by the situation of the abscess.

(1) *Steps of transpleural operation.*—The patient should be turned over to the sound side as little as possible consistent with a satisfactory exposure of the area of operation, as it is important to avoid restricting the movements of the sound lung An incision 4 inches long is made over and in the long axis of the 9th or 10th rib with its centre over the mid-axillary or posterior axillary line. The rib is resected subperiosteally for the whole length of the incision. The rib chosen must not in any case be higher than the 8th, or the next step may be impossible. A clean-cut incision is made through the periosteum and the pleura is opened. The diaphragm will present, and, if it is pushed up by

abdominal wall must be carried out in the theatre. If a differential diagnosis can be made, the incision is planned so as to provide the most ready access to the organ at fault; otherwise, the midline sub-umbilical incision is indicated. (Fig. 468, D.) In general terms, it may be laid down that the actual cause of the diffuse peritonitis, whether it be a perforated gastric or duodenal ulcer, a gangrenous appendix or gall-bladder, or whatever else, *must* be dealt with, if recovery is to be achieved, so that further infection from that source may be prevented Whereas drainage alone will be life saving in an inflammation of the appendix, the gall-bladder, the pancreas or the pelvic organs, it is usually necessary to close perforations of the stomach or duodenum

The writer has never seen a ruptured ulcer recover when the operation was limited to the drainage of an unlimited peritoneal extravasation. This observation does not apply to the incision and drainage of peri-gastric or peri-duodenal abscesses from leaking ulcers where Nature has already *completed the process of localization.* Details of the operations required will be found in the appropriate sections.

Flushing the peritoneal cavity.—This is seldom employed, exceptions being in the clearance of grossly contaminated food particles and fæcal extravasation.

The " toilet " of the peritoneum is usually limited to gentle swabbing or suction in the neighbourhood of the affected organ, in order to remove collections of pus or other contaminated fluid.

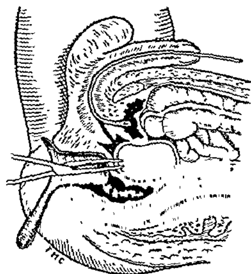
Drainage.—Where there is free fluid, which might be harmful, and which cannot be entirely removed, there is a natural inclination to drain. Of late a reaction has set in against drainage, and the following objections have been raised, viz. (1) that the peritoneal exudate may be beneficial rather than harmful; (2) that the peritoneum is well able to control infections if the primary focus is dealt with; (3) that the drainage tube generally has to work against gravity; (4) that in a very few hours the tube becomes walled in with adhesions and therefore drains only its own track; and (5) that the presence of a tube tends to form adhesions, may determine an intestinal obstruction, and is generally dangerous.

There is no doubt that the peritoneum has great powers of resisting and overcoming infection. These powers have probably been greatly enhanced by the advent of the chemotherapeutics and the antibiotics, particularly perhaps terramycin. Discriminate use in their administration is essential.

When drainage is required rubber tubes are most generally useful, but they should always be soft. It is better to soften a tube by cutting it in a spiral fashion along its length rather than by making lateral holes Omentum or even a knuckle of small bowel is very apt to find its way into holes and may become strangulated, and may be withdrawn from the abdomen when tubes are removed. To reduce the liability to this accident it is wise to turn the tube round once or twice every day. A roll or strand of rubber sheeting, such as dentists use, is

the table. It is imperative that the bladder be empty, and a catheter should be passed on the operating-table. A short Kelly's rectal speculum is inserted, and at its extremity the front wall of the rectum is exposed and the site of the abscess defined. The presence of the abscess must be confirmed by the exploring needle and syringe. When the pus has been demonstrated the needle is left *in situ* and a pair of sinus forceps or a knife is then passed along by the side of the needle and through the rectal wall into the abscess. (Fig. 475). There is nothing gained by making the incision in any special direction, nor is it necessary to attempt to make the opening valvular. The opening is sufficiently enlarged to allow the passage of a little-finger-size drainage-tube. This should be long enough to extend beyond the anal margin, to which it should be attached by a single silkworm-gut suture. The abscess cavity does not require emptying by pressure from above, nor should it be irrigated. The tube may be removed in about four days, for by that time the track should be well established. Discharge ceases quickly, and it is characteristic of these cases that recovery is rapid. As the small intestine is pushed up by the gradual collection of fluid in the pelvis, there is little risk of injury, but as the abscess contracts the bowel may be drawn down to the floor of the pelvis where it may become kinked and obstructed. When the abscess is a complication of appendicitis, an operation for removal of the offending organ must be considered. As a general rule subsequent laparotomy should be postponed for 6 or more weeks.

Meteorism (paralytic or adynamic ileus).—Paralytic ileus is a condition usually supervening on septic peritonitis, in which intestinal obstruction occurs, not as a result of a mechanical block, but from paralysis of peristalsis. It is of infrequent occurrence to-day It usually appears 24–48 hours after operation, and presents the two features of intestinal obstruction and toxæmia There is cessation of the passage of gas and fæces, very often accompanied by abdominal distension. Colicky pain is absent but the distension causes great discomfort. Regurgitant vomiting of the typical dirty-brown fluid is common, but fæculent vomiting rare The face becomes drawn and anxious, the tongue dry, the pulse- and respiration-rate steadily increase, and pulse-tension becomes progressively lower. Restlessness develops and thirst increases as toxæmia is established


Fig. 475.—Opening a pelvic abscess using Kelly's short speculum and sinus forceps.

Rational treatment can only be based on the assumption that there

the abscess, it will be easy to suture its upper surface to the incised parietal pleura (*see* p. 884). In this way the pleural cavity is shut off. The diaphragm is then incised and the abscess opened. A drainage-tube of little finger size is inserted, and the wound partially sutured.

(2) *Drainage from below.*—This operation, of less general value than that just described, is carried out through an incision, parallel with the rib cartilages, in the right hypochondrium, beginning just outside the linea semilunaris and extending outwards for 3 inches. The edge of the liver will probably be adherent to the parietal peritoneum, the general cavity in the vicinity being occluded. The abscess is opened by separating the adherent liver from the parietes.

(3) *Drainage from behind after excision of the 12th rib.*—This is the method associated with the names of Ochsner and Graves. An incision is made along the length of the rib; after its removal a transverse incision is made through the attachment of the diaphragm. The retroperitoneal tissue is opened above the kidney. The abscess is found by working upwards and inwards with the finger (*see* Fig. 376, p. 887).

Pelvic abscess.—Occasionally, after operation for appendicitis or diffuse peritonitis, a secondary abscess forms in the recto-vesical pouch or in the pouch of Douglas. The characteristic features are pain, tenesmus with passage of mucus, patulous anus and a rounded tender swelling bulging the anterior wall of the rectum within easy reach of the finger.

These abscesses may be drained from above or below, the latter route being by far the most satisfactory.

Drainage from above.—This is generally done through the original incision, adhesions being gently separated by the finger until the abscess is reached. The operation is not without danger, less from the risk of re-infecting the general peritoneal cavity than of some injury to the intestinal coils forming the abscess-wall. Of these the latter is the more serious, and a small-intestine fæcal fistula is not an infrequent sequel An independent suprapubic mid-line incision is sometimes more satisfactory.

Drainage from below.—As the abscess increases in size it comes into close relation with the anterior wall of the rectum and tends to point in this situation and may be encouraged to do so by hot hip baths or hot water enemas It may rupture spontaneously into this part of the bowel.

Drainage can be effected either through the rectum or, in married women, through the posterior vaginal fornix. The latter avoids the risk of fæcal contamination, but in practice this risk can be dismissed and the rectal route is generally chosen and is in every way satisfactory. It should always be used when the abscess presents per rectum.

The rectum is usually empty as the result of tenesmus, but if not it should be cleared by a glycerine enema. The patient is placed in the lithotomy position, the buttocks being drawn well over the end of

refreshing slumber. The idea of fighting sleep during the day in the expectation that at night Morpheus will oblige is fallacious. Most patients derive comfort from warmth to the abdomen and it may do more than merely soothe, for sometimes intestinal movements are stimulated. The inhalation of 95 per cent. oxygen is certainly helpful and may be given with a proper face mask for three hours out of four and continued in that way for 24 hours. When the measures outlined entirely fail, spinal anæsthesia may be tried, but, although the result is sometimes dramatic, it is more often disappointing.

When all efforts are unavailing and the condition is deteriorating,

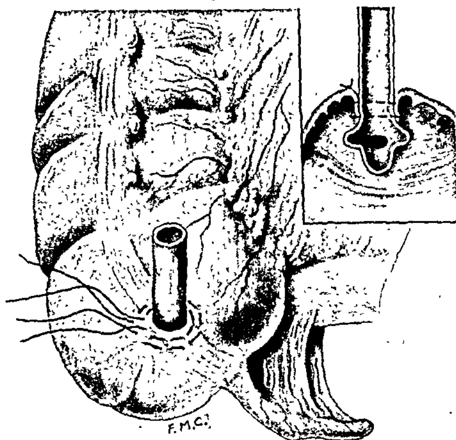


Fig. 476.—Cæcostomy by purse-string invagination. A de Pezzer catheter is a very convenient form of tube.

as shown by a rising pulse, increasing distension and continued intestinal regurgitation, the question of draining the intestine externally will have to be considered. In appendicitis so many cases improve after the spontaneous development of a fæcal fistula that nature's plan may be imitated. Not infrequently the original incision is over the cæcum which is adherent to the parietes, making it safe to open that part of the bowel at the bottom of the wound after removal of some of the sutures. If this is followed by a copious discharge of intestinal contents, the good effect may be dramatic. Should there be no result, flushing

are certain ætiological factors with which the surgeon has to deal. Toxæmia, the result of the absorption of bacterial products either from the peritoneum or from the bowel, is probably the most important. Exhaustion of the neuro-muscular mechanism and loss of tone of the muscle of the bowel wall, as the result of distension, are other factors. *Loss of fluid and chlorides*, the consequence of vomiting and hyper-secretion into the bowel, are also very important. A possible psychological feature must not be overlooked, for the patient may be anxious because vomiting persists, or the bowels do not act, or natural sleep is denied him. This state is often increased by the undisguised apprehensive anxiety which is sometimes allowed to surround the sick-bed.

General management.—What has already been said about the treatment of peritonitis (p. 1144) applies to this condition. If we only knew of some specific antitoxin it would be the sheet anchor of treatment, but unfortunately there is much doubt about the efficiency of any of the sera at present employed. Chemotherapy and the antibiotics are often helpful but are not specifics. Small (e.g. gr. $\frac{1}{6}$) repeated doses of morphia to put the bowel at rest and allow it to recover are indicated.

If the toxins cannot be cleared out by the bowel or neutralized they must be diluted, and excretion by the kidneys promoted. These objects are attained by an abundant intake of fluid. Exhaustion calls for food and stimulant. Tissue nourishment is supplied by intravenous chlorides and glucose or Ringer's solution, and stimulant may take the form of small doses of strychnine hypodermically Patients who have been accustomed to alcohol should not be denied their favourite fillip, for a very serious illness is not the time for the blue ribbon propaganda of the temperance advocate. The decompression of the intestines to mitigate the harmful distress of distension and to encourage the return of tone to the bowel wall is most helpful, and it is particularly in these cases that we may come to rely more and more on the Miller-Abbott tube. But if that apparatus is not available, the Ryle or Wagensteen tube can do a great deal.

When the viscus has been emptied the patient may be allowed small drinks if thirst is insistent. Generally speaking, very hot drinks are better than cold; the practice of giving ice to suck has no saving virtue whatever. In these cases nature cries out for sleep, and this is always most beneficial. The measures detailed may bring slumber, but if they do not, and drugs are necessary, it should be remembered that combinations of sedatives may act well Aspirin, 10 grains crushed up with $\frac{1}{4}$ grain of morphine, given as a powder, is often successful. If the route by the mouth is not considered advisable, potassium bromide, 20 grains, with aspirin 15 grains given in emulsion *per rectum* is useful and may be combined with a very small intravenous dose of morphine ($\frac{1}{12}$–$\frac{1}{16}$ grain) or repeated small doses of this drug may be used. Patients should be encouraged to court sleep in every possible way, for a few minutes every now and then may mean in the aggregate quite a

Whether the diffuse and the encysted types are merely stages in the same disease, or whether they depend for their differentiation on strains of pneumococcus of varying virulence, is a question not yet decided. If we could be sure that every diffuse-type case had a chance of becoming encysted, there would be a great deal to be said for deferring operation.

Chemotherapy and the antibiotics now play the major part in treatment, but if the condition is not controlled by these means or there is grave doubt as to diagnosis, operation may be indicated. Localized collections of pus are better treated by incision with or without drainage. In practice it is less harmful to open the abdomen in this disease with little hope of improvement than it is to miss the opportunity of removing an acutely inflamed appendix complicated by diffuse peritonitis.

Technique.—In the acute cases the abdomen is better opened over the appendix region so that if that organ is at fault it can be readily removed. A small incision is employed in the first instance as the nature of the pus may settle all doubts. Thick, slimy, non-offensive exudate is characteristic of pneumococcal infection. Drainage is better avoided when the exudate is very watery and the coils of intestine distended. In other circumstances, or if there is the slightest suspicion of an appendicular origin, drainage is a wise procedure. In the chronic localized form a pointing abscess near the umbilicus should be incised there; in other cases a midline incision below the umbilicus will be the most direct route to the collection. Abscesses in this type of peritonitis do not tend to point *per rectum*. Drainage by a small tube is all that is required. In the very ill patients with marked constitutional disturbance chemotherapy may be helpful after the incision of an abscess just as blood transfusion may be so useful in the debilitated chronic case.

Results.—The diffuse type used to be attended by a deplorably high mortality rate but this has been greatly reduced as a result of chemotherapeutic treatment, blood transfusion, etc. The cases in which a localized collection can be opened and drained do very well.

TUBERCULOUS PERITONITIS

Of the three types of tuberculous peritonitis, the *ascitic*, the *fibrous* or *adhesive*, and the *ulcerative*, only the first is usually considered amenable to surgical treatment. If operation has to be done in either of the other types it is undertaken rather with a view to confirming a diagnosis or dealing with a complication, generally intestinal obstruction, than in the hope of effecting a cure. It is quite possible that the so-called *ulcerous* type is really the final stage of a caseating mesenteric-gland tuberculosis, and intervention, if it is to be successful, must take place at a much earlier stage. It seems certain that operations, in these later stages, do more harm than good, they are often

the cæcum with very hot water may produce an outpouring, or a catheter may be passed along the ileum and the small bowel irrigated. If these measures fail, the surgeon has the choice of making a formal cæcostomy or enterostomy or opening the abdomen for exploration and to effect an anastomosis between the small bowel above an inflammatory lesion or localized paretic area and the unaffected bowel beyond.

Cæcostomy.—The condition of the patient does not allow an elaborate ritual, and local anæsthesia may be used. An incision is made as for appendicectomy or, if this has been done, the wound is re-opened. The subsequent steps of the operation are as described at p. 1028. The tube from the cæcum is led through the dressings and connected to a tube leading to a receiver. If improvement is to follow it does so at once The tube may be removed at the end of a week or ten days. When the method shown in Fig. 476 is employed the opening may be expected to close spontaneously in two to four weeks after the removal of the tube. Otherwise formal closure by operation will be required (*see* p. 1038).

Enterostomy.—If it be decided to drain the small intestine, the site for the opening should be as low as possible to guard against the risk of starvation by too great a loss of intestinal contents and of the absorbing area. The subsequent steps of the operation are as described at p. 1050. After immediate drainage of the intestine has ceased, the bowel may be washed out with saline solution. Though this is a life-saving operation, it has the grave disadvantage that a fæcal fistula may form high up in the intestinal tract. The greatest care is necessary to prevent excoriation of the skin, and painting with white of egg or milk is helpful. If there is copious persistent escape of intestinal contents, the fistula must be closed as soon as possible.

Pneumococcal Peritonitis

Pneumococcal peritonitis usually occurs in female children under ten. It may be acute (diffuse) or chronic (encysted), and it may be primary, or secondary to some focus elsewhere, especially pneumonia. In the acute form it presents most of the characters of an acute diffuse peritonitis, and it is almost impossible to make a differential diagnosis before operation. The distinguishing features are (1) the presence of some other infective focus, especially pneumonia, (2) onset with rigors or herpes labialis; (3) pain, vomiting, and *diarrhœa*; (4) early free fluid; (5) marked leucocytosis, (6) preponderance among females and children. The temperature does not run high, and if the patient is going to recover or to reach the chronic stage the symptoms gradually subside over a period of 12 to 14 days.

Should the chronic stage supervene, an abscess forms painlessly, and localizes below the level of the umbilicus. The diarrhœa ceases, but the temperature fluctuates and there is marked loss of weight. Finally, if untreated, the abscess usually discharges at the umbilicus, resulting either in recovery, or in secondary infection, when death may follow.

Whether the diffuse and the encysted types are merely stages in the same disease, or whether they depend for their differentiation on strains of pneumococcus of varying virulence, is a question not yet decided. If we could be sure that every diffuse-type case had a chance of becoming encysted, there would be a great deal to be said for deferring operation.

Chemotherapy and the antibiotics now play the major part in treatment, but if the condition is not controlled by these means or there is grave doubt as to diagnosis, operation may be indicated. Localized collections of pus are better treated by incision with or without drainage. In practice it is less harmful to open the abdomen in this disease with little hope of improvement than it is to miss the opportunity of removing an acutely inflamed appendix complicated by diffuse peritonitis.

Technique.—In the acute cases the abdomen is better opened over the appendix region so that if that organ is at fault it can be readily removed. A small incision is employed in the first instance as the nature of the pus may settle all doubts. Thick, slimy, non-offensive exudate is characteristic of pneumococcal infection Drainage is better avoided when the exudate is very watery and the coils of intestine distended. In other circumstances, or if there is the slightest suspicion of an appendicular origin, drainage is a wise procedure. In the chronic localized form a pointing abscess near the umbilicus should be incised there; in other cases a midline incision below the umbilicus will be the most direct route to the collection. Abscesses in this type of peritonitis do not tend to point *per rectum*. Drainage by a small tube is all that is required. In the very ill patients with marked constitutional disturbance chemotherapy may be helpful after the incision of an abscess just as blood transfusion may be so useful in the debilitated chronic case.

Results.—The diffuse type used to be attended by a deplorably high mortality rate but this has been greatly reduced as a result of chemotherapeutic treatment, blood transfusion, etc. The cases in which a localized collection can be opened and drained do very well.

TUBERCULOUS PERITONITIS

Of the three types of tuberculous peritonitis, the *ascitic*, the *fibrous* or *adhesive*, and the *ulcerative*, only the first is usually considered amenable to surgical treatment. If operation has to be done in either of the other types it is undertaken rather with a view to confirming a diagnosis or dealing with a complication, generally intestinal obstruction, than in the hope of effecting a cure. It is quite possible that the so-called *ulcerous* type is really the final stage of a caseating mesenteric-gland tuberculosis, and intervention, if it is to be successful, must take place at a much earlier stage. It seems certain that operations, in these later stages, do more harm than good, they are often

followed by fæcal fistula and death, though there are brilliant exceptions. In the *fibrous* type, results are better, poor as they are, and there is a chance of relieving obstruction if the area affected is more or less localized It is as well to say definitely that, in the absence of intestinal obstruction, the value of an operation to cure cases of either of these two types is very doubtful. In the *ascitic* type an exploratory laparotomy is often followed by complete recovery, and is attended by a very low mortality.

In cases that have been for long at a standstill the rapid improvement which may follow surgical intervention fully justifies the use of laparotomy in this disease. None the less, operation should only be regarded as an incident in the management and those general and hygienic measures which tuberculosis always demands must be continued for long afterwards. The newer antibiotics may be expected to improve the outlook considerably.

Technique.—The operation consists in a median sub-umbilical laparotomy, the release of fluid, and closure without drainage. The peritoneum should be sewn up with absorbable sutures and the rest of the abdominal wall in one layer with through-and-through silkworm or other strong non-absorbable material. Layer suturing with catgut seems to encourage the development of tuberculosis in the wound. The Mayos reported good results after removal of tuberculous Fallopian tubes in adults, but this step is not considered advantageous, at any rate as a routine, in this country.

In the *adhesive* type, the mere opening of the peritoneal cavity sometimes starts the curative process. Quite often cases that have been at a standstill, or even going downhill, begin to improve at once and go on to complete recovery. In this type the surgeon must resist the temptation to separate adherent coils of intestine, for not only is this step unnecessary but it is very likely to be followed by fæcal fistula.

Contra-indications.—Operation should not be advised until the patient has had the chance of a thorough trial of conservative measures under the best conditions obtainable. A well-arranged and supervised anti-tuberculosis regimen is an essential part of the after-treatment of cases subjected to operation. In cases with generalized or pulmonary tuberculosis, or with evidence of tuberculous enteritis, surgical interference is useless.

Results.—In comparing results obtained by medical and by surgical treatment, the after-histories have not been continued long enough to allow more than a speculative estimate. A considerable number of the cases regress under medical management and surgical intervention will not save them. But cases that improve considerably under a medical regimen, and then come to a standstill, often recover completely after simple laparotomy. Rapid loss of weight and diarrhœa are of very grave prognostic import.

TUBERCULOUS MESENTERIC NODES

Operation may be necessary for tuberculous nodes which are giving rise to symptoms or complications. These nodes generally arise in the mesentery of the lower ileum or the ileo-colic angle, and are probably infected with tubercle bacilli from milk, after resistance has been lowered by undetermined causes. They may be considered, therefore, as a local condition comparable in many respects with tuberculous nodes in the neck. They occur in three forms, which are merely variations in degree. In the *first* stage the gland is enlarged but presents no unusual appearance, and its serous covering is not affected. In this stage symptoms may be complained of, chiefly the characteristic short-lived colicky pain, but complications other than peristaltic anomalies do not occur. In the *second* stage caseation is present, and the gland may be transformed into a large collection of pultaceous material surrounded by a thin-walled capsule. It is this stage which is dangerous, for the peritoneal covering becomes affected and adhesions may form between neighbouring glands or between the gland and a loop of intestine. Or the capsule may give way, flooding the peritoneum with caseous material, or more gradually a condition may arise which is indistinguishable from the so-called ulcerative type of tuberculous peritonitis. The *third* stage, of calcareous degeneration, is a quiescent stage in which the peritoneum is intact over the gland, and complications are less likely. The stage which justifies operation is the second or caseating phase and that alone. It must be remembered that usually all three stages are present together in cases of long standing.

Complications.—As complications are a very important " risk " in these cases, it is as well to consider their frequency. In a paper based on 50 cases, read before the Medical Society of London,* H. W. Carson reported an intestinal kink in 5 cases of 39 with " typical " symptoms, and in the 11 cases with " atypical " symptoms there were 3 cases of intussusception and 5 cases of other types of intestinal obstruction, so that in the 50 cases there were 13 instances of actual or potential obstruction, in one case causing the death of the patient. G. H. Colt and G. N. Clark† only encountered 13 examples of obstruction among 239 cases reviewed.

Indications for operation.—Not infrequently, attacks of abdominal pain attributed to tuberculous nodes in the mesentery are really due to mild recurrent appendicitis. For this reason, unless there is some contra-indication such as the presence of active tuberculosis elsewhere, exploration should usually be advised. It is something of a tragedy to condemn a patient to a tedious antituberculous regimen, or to some degree of invalidism, when so simple an intervention as removal of the appendix may bring about cure. But the converse is true, and when patients are not cured by removal of the appendix there is a tendency to

* *Med Soc Lond. Trans.*, 1918 xli, 220.
† *Surg. Gyn. and Obstet*, Dec. 1937, lxv, 771.

attribute residual symptoms to tuberculous nodes which may have been discovered at operation. The accidental discovery of calcareous nodes on X-ray examination does not in itself justify operation, but laparotomy should certainly be considered if the patient is suffering from symptoms not otherwise explained. In certain circumstances the question arises whether the removal of the glands will bring about cure; the late Mr. Carson advocated removal and his practice has been followed by G. H. Colt (*vide supra*).

Technique.—The abdomen is opened in the midline below the umbilicus, and the mesentery is examined, beginning at the ileo-cæcal junction. If the conditions are such that intestinal obstruction appears likely, bands or adhesions may be dealt with, but the surgeon must always remember that as a result the lumen of the bowel may be opened and must be very carefully repaired. A single well-localized active-looking caseous node certainly invites removal, but several such nodes adhering or forming a large mass are better left alone. The nodes cannot be shelled out but must be removed by dissection, the whole node being cleanly excised with the knife. It is not advised to incise and curette, though this may be necessary when nodes burst during attempts at removal or are especially adherent. After removal the greatest care must be taken to sew up the incision in the serosa. In some cases, where the latter is adherent to both surfaces of the node, the removal leaves a hole in the mesentery, and this should be closed. Great care must be taken not to puncture or otherwise damage the mesenteric vessels. Jamieson and Dobson* give warning of the close relationship of the ileo-colic chain of glands to the ileo-colic artery and vein.

In rare instances it may be necessary to resect a portion of intestine. This will especially arise when a considerable mass of nodes abuts on the mesenteric border of the intestine. In these circumstances the bowel may be stretched over the nodes or may be kinked or narrowed or ulcerated at this point. Care must be taken to see that the nodes do not extend up to the root of the mesentery as this would entail an unnecessarily large resection. When resection seems unwise, a short circuit may be substituted with confidence In many cases the nodes become quiescent after mere opening of the abdomen and this should be borne in mind when their removal would entail a severe operation. In every case the intestine is examined for ulcers or kinks, and a general survey undertaken of the abdominal viscera for other evidences of tuberculosis The appendix should always be removed and the abdomen closed without drainage. Adhesions are apt to follow intervention in these cases, and Colt recommends that the abdomen should be filled with saline solution at the conclusion of the operation. Catgut is used throughout for the peritoneal sutures, with through-and-through silkworm-gut for the other layers

If complications are present they must be treated on general

* *Lancet*, 1907, i, 1141

principles. In obstruction it is useless to make an artificial anus proximal to the obstruction, and an anastomosis short-circuiting the mass of nodes will probably be the best means of relief.

Results.—The operative mortality is about 5 per cent., but this includes the cases complicated by intestinal obstruction. Of those who recover, the majority are relieved of their symptoms, though in a small proportion tuberculosis develops elsewhere or again becomes active in the abdomen. Over a long lifetime tubercle bacilli in the nodes may remain " not dead but sleeping ".

INDEX